THE

GEOLOGICAL MAGAZINE:

OR,

Monthly Journal of Geology:

WITH WHICH IS INCORPORATED

"THE GEOLOGIST."

NOS. CCLXXXIII. TO CCXCIV.

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NEW SERIES. DECADE III. VOL. V.

JANUARY—DECEMBER, 1888.

LONDON:

TRÜBNER & Co., 57 AND 59, LUDGATE HILL.

F. SAVY, 77, BOULEVART ST.-GERMAIN, PARIS.

1888.

HERTFORD:
PRINTED BY STEPHEN AUSTIN AND SONS.

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M32
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THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. V.

No. I.—JANUARY, 1888.

ORIGINAL ARTICLES.

I.—The Natural History of Lavas as Illustrated by the Materials ejected from Krakatoa.[1]

By Prof. John W. Judd, F.R.S., Pres.G.S.

SHORTLY after the great volcanic eruption at Krakatoa, in August, 1883, the Royal Society appointed a Committee to collect and sift the records of that remarkable outbreak and to study the effects which appear to have resulted from it. The investigation of the volcanic phenomena and of the materials ejected from the volcano having been committed to me, I have been led to some conclusions of considerable geological interest, the full discussion of which could scarcely find a place in the report which has been published by the Committee. It is these general results which I propose to discuss in the following communication.

For the opportunity of studying the different rocks of Krakatoa, I am indebted to many correspondents who have supplied me with the necessary materials, and especially to M. René Bréon, who visited the volcano shortly after the eruption.

The central crater of Krakatoa has always given vent to lavas of the same general type—namely pyroxene-andesites, or rather, as they should perhaps be called, dacites; though from a lateral vent a great mass of basaltic lavas and tuffs were ejected during one epoch in the past history of the volcano.

It is the pyroxene-andesites to which I especially desire to call attention; for their study, in connection with that of other rocks of the same class, suggests a number of very interesting generalizations. The pyroxenes contained in these rocks belong to two species. The most abundant is one crystallizing in forms belonging to the orthorhombic system, in the composition of which the base magnesia predominates over the lime; it is a *ferriferous enstatite* or *hypersthene*. The less frequently occurring pyroxene is one crystallizing in forms of the clinorhombic system, in which lime preponderates over the magnesia: it is a true *augite*. Not only do these two forms of pyroxene always occur together, but they are sometimes found intergrown with their corresponding crystallographic planes in parallel positions. From the predominating pyroxene in these rocks they

[1] A paper read at the Meeting of the British Association in Manchester (September, 1887).

are frequently described as "enstatite-andesites" or "hypersthene-andesites."

Now these andesites of Krakatoa have been very carefully investigated, both by chemists and mineralogists, during the last four years. The memoirs of Richard,[1] Renard,[2] Sauer,[3] Reusch,[4] Oebbeke,[5] Von Lasaulx,[6] Carvill Lewis,[7] Joly,[8] Bréon,[9] Waller,[10] and especially of Verbeek, Retgers, and Winkler,[11] leave us little indeed to be desired in this respect. We have not only a number of independent analyses of the rocks themselves, but also of each of the minerals contained in them; these having been isolated by the refined methods of modern petrography. Each of the minerals too has been submitted to searching optical investigations, so that there are few rocks of which we can be said to know the chemical composition and mineralogical constitution more thoroughly.

It very fortunately happens that there are several other rocks belonging to the same general type which have also been investigated in the same thorough manner. Those that I have especially chosen for comparison are (1) the ancient and modern lavas of Santorin which have been studied by Zirkel, Karl von Hauer,[12] and especially by Prof. Fouqué.[13] (2) The lava of Buffalo Peaks, Colorado, for the description of which we are indebted to Mr. Whitman Cross[14] of the U.S. Geological Survey, and (3) the more ancient but very similar lavas of our own Cheviot Hills, which have been so carefully studied and described by Mr. Teall[15] and Dr. Petersen.[16]

Now these rocks, coming from such widely different localities, all agree in the minerals of which they are made up. They all include crystals of several species of plagioclastic felspar, the most basic or those containing a large per-centage of lime being very abundant; there are in all of them two pyroxenes, namely, ferriferous enstatite and augite, the former being present in greatest quantity; and they all contain magnetite with some ilmenite. In addition to the porphyritic crystals of these minerals, there is a base or ground-mass sometimes consisting of a nearly pure glass, at other times of glass which has undergone a greater or less amount of devitrification, whereby it has passed into a more or less perfectly stony mass.

[1] Comptes Rendus, Seance du 19 Novembre, 1883.
[2] Bull. de l'Acad. Royal de Belgique, 3re ser. t. vi. (1883).
[3] Berichte der Naturf. Gesellsch. zu Leipzig, 1883, p. 87.
[4] Neues Jahrb. für Min. etc. 1884, bd. ii.
[5] *Ibid.* 1884, bd. ii. p. 32.
[6] Sitzg. d. niedersch. Gesch. in Bonn, Sitz. vom 3 December, 1883.
[7] Proc. Acad. Sc. Philadelphia, 1884, p. 185.
[8] Roy. Dublin Soc. n.s. vol. iv. p. 291.
[9] "La Nature," 13me. Année (1885), p. 373.
[10] Birm. Nat. Hist. and Microscop. Soc. Rep. and Trans. for 1883, p. vi (March, 1884).
[11] Krakatau, pp. 185–324.
[12] Neues Jahrb. für Min. etc. 1866, p. 769.
[13] Santorin et ses Eruptions, 1870.
[14] Bull. U. S. Geol. Survey, No. 1 (1883).
[15] Geol. Mag. Ser. II. Vol. X. pp. 100–109 and 252–263.
[16] Mikroscopische und Chemische Untersuchungen am Enstatitporphyrit aus den Cheviot Hills, Kiel, 1884.

That there is a very great similarity in the composition of the glassy basis of these various rocks is shown by the following analyses :—

	Glass of Santorin lava (Fouque).	Glass of Cheviot rocks (Ebers in Petersen).	Glass of Krakatoa (Calculated).
Silica with Titanic acid.	71·5	71·1	72·8 (68·8)
Alumina	16·8	14·6	14·7 (15·9)
Oxides of Iron	0·8	3·3	1·8 (5·1)
Lime	0·8	2·9	3·4 (3·8)
Magnesia.....	0·7	0·3	1·0 (1·2)
Soda	7·4	2·4	4·1 (5·1)
Potash	2·0	5·4	2·2 (1·1)

The statement of these and subsequent analyses has been calculated independently of water and "loss on ignition," not that I regard these volatile materials as being unimportant, but because the methods adopted by different chemists for their determination are so various, that their inclusion would make the comparisons less satisfactory. The analysis of the Krakatoa-glass is calculated from the bulk analysis of the pumice, compared with that of the several crystalline constituents, the proportion of each of these being known. I have placed in brackets besides this calculated analysis the actual analysis made by Retgers; but concerning this last it must be remarked that it is the analysis of the glass of the dust which fell nearly a hundred miles away from the volcano, from which some of the lighter particles had been winnowed out in its passage through the atmosphere. Moreover, it was found impossible to separate the finer grains of magnetite from this glass, so that, as admitted by its author, the silica is too low, and the iron-oxides too high. The same remark probably applies, though perhaps in a less degree, to the analysis of the glass of the Cheviot-rocks.

A very obvious defect in our modern methods of petrographic nomenclature and classification is that they are based on a *qualitative* and not on a *quantitative* determination of the mineralogical constitution of the rocks. When the *relative proportions* of the mineral constituents of a rock are taken into consideration, as well as their *nature*, we are led to some very interesting considerations.

At present, so far as I am aware, we have no other simple method available for determining the relative proportions of the constituents of a rock than the one suggested by Sorby, that of drawing the outlines of crystals seen in section under the microscope, and then cutting out and weighing on a delicate balance the portions of paper representing each of the minerals. By obtaining a photograph instead of a drawing of the section, as was suggested by the late Sir Richard Daintree, one source of error in such determinations may perhaps be removed. Of course, if we have a bulk-analysis of the rock, and analyses of each of its mineral constituents, it is possible to calculate the proportions which these latter bear to one another.

By a series of determinations of this kind, checked in a great number of different ways, I have convinced myself that the constitution of the Krakatoa-rock may be represented as follows :—

	in one hundred parts by weight.		
Glass	90·0	...	(91·0)
Felspars	6·5	...	(6·0)
Enstatite	1·4	...	(1·36)
Augite	0·6	...	(0·64)
Magnetite	1·5	...	(1·00)

The estimate made by Retgers, which I have placed in brackets beside my own, was based on the study of a dust which fell at Buitenzorg. But this material cannot exactly represent the original rock, seeing that during the passage of the dust through the air, the magnetite and other heavy minerals tend to fall sooner than the glass, while, on the other hand, excessively fine particles of the latter are left behind in the atmosphere. Hence, the dust which falls at any particular point cannot possibly be taken as a fair sample of the whole mass of the rock.

The Krakatoa-rocks, it will be seen, consist of two very distinct materials, a crystalline portion making up one-tenth of the whole mass, and a colloid or glassy portion which forms no less than nine-tenths of the whole. The chemical composition of the whole rock and of these two constituents is as follows :—

	Composition of rock.		Composition of Glass forming 90 % of rock.		Composition of Crystals forming 10 % of rock.
Silica with Titanic acid.	70·0	...	72·8	...	48·7
Alumina	15·0	...	14·7	...	19·3
Oxides of Iron	4·0	...	1·8	...	18·0
Lime	3·7	...	3·4	...	6·9
Magnesia	1·3	...	1·0	...	2·5
Soda	4·1	...	4·1	...	3·8
Potash	1·9	...	2·2	...	0·8

Now all the other rocks, to which I have referred, consist of a crystalline and a glassy portion, and these have nearly the same composition as those two portions of the Krakatoa-rock. All the rocks contain the same minerals, felspar, enstatite, augite, and magnetite; the analyses of which yield very similar results. In all of them, too, the relative proportions of these several minerals do not appear to be very different from that we have found to exist in the Krakatoa rocks. I have already shown that the composition of the glass in these different rocks is not very dissimilar. Nevertheless the ultimate chemical composition of these various rocks, all of which are called by petrographers by the same name of "enstatite-andesite," or "hypersthene-andesite," is found to differ in the most remarkable manner.

This fact is illustrated by the following table :—

	Rock of Santorin dykes.	Buffalo Peaks lava.	Cheviot rocks.	Recent lavas of Santorin.	Rocks of Krakatoa.
Silica	51·8	56·6	64·5	67·4	70·0
Alumina	20·1	16·2	16·3	14·8	15·0
Oxides of Iron.	11·6	9·3	5·1	6·4	4·0
Lime	11·9	7·8	4·4	3·7	3·7
Magnesia	3·4	4·6	4·2	1·0	1·3
Soda	1·1	3·1	3·4	4·4	4·1
Potash	0·1	2·4	3·1	2·3	1·9

At one end of this series we have a rock which is *basic* in its

composition, at the other end one which is distinctly *acid*; while the others may be fairly classed as intermediate between those types. Yet all these rocks contain precisely the same mineral constituents, and the difference in their chemical composition is clearly due to the very different proportions in which their more basic constituents, the porphyritic crystals, are mingled with the acid material, the enveloping glass.

Of course any variations in the relative proportions of the different felspars, pyroxenes and of magnetite will to some extent modify the ultimate chemical composition of the rocks; but I am convinced that in all these rocks the proportion of the several minerals to one another does not vary very greatly; in all of them felspar-crystals greatly predominate over the pyroxenes and magnetite; and among the pyroxenes the orthorhombic enstatite is almost always more abundant than the clinorhombic augite.

Assuming, what is certainly not far from the truth, then, that the crystalline and glassy portions of these rocks have respectively the same composition in all of them, we can calculate from the data before us the relative proportions of the crystalline and glassy portions of each of these rocks. The result is as follows :—

	Glassy base (parts in 100).	Crystalline portion (parts in 100).
Most basic dykes at Santorin	10	90
Other dykes at Santorin	10—35	90—65
Buffalo Peaks lava	$33\frac{1}{3}$	$66\frac{2}{3}$
Cheviot-rocks	66	34
Recent lavas of Santorin.....	80	50
Lavas of Krakatoa	90	10

It will be seen that at one end of the series we have the crystalline constituent nine times more abundant than the glass, and at the other end the glass nine times as abundant as the crystalline constituent. But in spite of this, the rocks according to the ordinary system of nomenclature, based on mineralogical constitution, must be called—and indeed have been called—by the same name, that of "hypersthene-andesite" or "enstatite-andesite."

Let us now turn our attention to another remarkable set of facts with respect to these lavas of Krakatoa. It is a very striking circumstance that all the materials ejected from the central vent of Krakatoa agree in a very marked manner in their chemical composition and mineralogical constitution, *both qualitatively and quantitatively*. They all contain about 70 per cent. of silica, and are composed of 90 per cent. of base, with ten per cent. of porphyritic crystals; these last consisting of plagioclase felspar, enstatite, augite and magnetite, always in nearly the same relative proportions.

Nevertheless, while presenting this almost absolute identity in chemical and mineralogical constitution, we find among these products of Krakatoa three distinct types of materials—exhibiting the most striking differences in their physical characters and in the mode of their behaviour during ejection. These differences are seen to be dependent on peculiarities presented by the base or ground-

mass of the rocks, the crystalline or porphyritic portions being the same in all three types.[1]

In most of the older ejections the base is of a dull reddish-grey tint, and stony texture. Under the microscope the glass of the base is seen to have undergone a great amount of devitrification, and to be filled by a mesh of microlites of felspar, pyroxene, hornblende and iron-oxides, between which minute portions of the glassy base are left. Frequently this base is cavernous, and in such cases the cavities are lined with beautiful crystallizations of quartz, tridymite and hornblende. These are probably the results of secondary alteration. The fact of water having percolated through the rock is shown by the more or less complete conversion of the magnetite into hydrated ferric oxide.

Associated with this porphyritic stony lava, we find a second type of rock, the base of which is of a jet-black colour and resinous lustre. This beautiful velvety black rock is an admirable example of a *porphyritic pitchstone*, and strikingly resembles the rock of the Cheviot Hills and some of the Santorin lavas. The base contains fewer microlites, but is crowded with crystallites, both belonites and trichites, and these not unfrequently, according to Retgers, form the variety of spherulites called by Rosenbusch "felso-spherites." The rock, moreover, often exhibits a fluidal structure.

In the third type of rock occurring at Krakatoa, we find the porphyritic crystals still the same, but embedded in an almost perfect glass, which is of a rich amber-brown colour when seen in large fragments, but almost colourless in thin sections by transmitted light. This rock has been called a *porphyritic obsidian*. Under the microscope, the glassy base of this rock is found to contain only a very few widely-scattered microlites and crystallites.

But the most striking difference between the base or ground-mass of these three types of lava becomes apparent when they are subjected to high temperatures. If a fragment of the stony lava or of the pitchstone be acted upon by a strong blowpipe-jet, urged by a foot-bellows, it may be rendered white-hot without exhibiting signs of fusion. But if we treat a fragment of the obsidian in the same way, we shall find that on approaching a white heat, it begins to melt, and in doing so swells up into a cauliflower-like mass, five or six times the size of the original. When this mass is cooled and examined, it is found to be a dirty brownish-white pumice, identical in all its characters with the material that was thrown out in such vast quantities during the last great eruption of Krakatoa. This identity in character is seen to be even more marked if we make thin sections of the natural and of the artificial products, and examine them under the microscope. In its behaviour the obsidian of Krakatoa behaves indeed precisely like the Marekanite of Okhotz and a glassy rock from Fife which I have previously described.[2]

[1] In the Report on "Krakatoa" by the Royal Society Committee, plates ii. and iii. are devoted to the illustration of the characters of the rocks of Krakatoa as exhibited in microscopic sections.

[2] Geol. Mag. Dec. III. Vol. III. (1886), p. 243. Quart. Journ. Geol. Soc. vol. xlii. (1886), p. 429.

In all these cases it is clear that the rocks contain a considerable proportion of volatile materials, which are given off at a high temperature.

When we come to study the several varieties of the lava of Krakatoa in the field, we are struck by remarkable differences in the mode in which they must have behaved while in a liquid condition. The stony lava and the pitchstone it is seen were extruded in massive lava-streams with an almost total absence of pumice or scoriæ; the obsidian, on the other hand, was almost wholly distended into a pumice, throughout which the porphyritic crystals of the rock are found entangled. It is evident that every part of the glass has been impregnated with the volatile constituents, which by their escape have caused its conversion into pumice, for the whole of the glass is drawn out into the finest rods and plates; indeed, it is only in the case of small fragments which have been suddenly cooled before the volatile ingredients have been permitted to escape, that we are able to judge of the characters of the glass from which the pumice was formed. By cutting blocks of pumice of definite size, and comparing their weight with that of masses of glass of the same size (this being easily determined when the specific gravity of the glass is known), I have been able to calculate the amount of distension which has taken place in the glass during its conversion into pumice. The more compact varieties of pumice have $3\frac{1}{2}$ times the bulk of the glass from which they were formed; in the more common looser varieties the distension has been at least $5\frac{1}{2}$ times the original; and in some varieties the bulk of the air-cavities is 7, 8 or even 9 times that of the enclosing glass.

The stony lavas and the pitchstones differ mainly in the amount of devitrification which the glassy base has undergone. And this we have every reason to believe was determined by the rate at which cooling took place. We find indeed every gradation between the one type and the other, just as we do in the Cheviot Hills; at Steerhope, near Yetholm, in that district, a great lava-stream may be seen, the central portion of which consists of a stony rock, while the superficial layers graduate into well-known pitchstone. There can be little doubt that, in the same way at Krakatoa, the more rapidly cooled portions of the stony lava have formed the porphyritic pitchstone.

But the obsidian of Krakatoa presents many very striking differences from the other two kinds of rock; and for some of these the more easy fusibility of its base affords a ready explanation. Thus, little knots of the pitchstone are often found scattered through the obsidian; and in the pumice formed from the obsidian these stand out in relief upon the abraded surfaces, in the same way as do the porphyritic crystals. Now when such knots of pitchstone are examined microscopically, the felspars in them are found to have undergone a most wonderful amount of corrosion; often the larger part of their bulk has been redissolved in the heated magma in which they have been enveloped, they are completely honeycombed, and sometimes reduced to mere skeletons.

Those who regard the bulk-analysis of an igneous rock as necessarily representing the composition of the magma out of which the minerals which compose it have separated, and who further consider the successive crops of crystals formed in a rock as being determined by the alteration in the composition of the residual magma by the constant separation of the basic minerals from, it will find it difficult to harmonize such views with the facts presented to us at Krakatoa.

It is difficult, in the first instance, to account for the separation of precisely the same minerals, the felspars, pyroxenes and magnetite, in magmas of such diverse composition as is represented in the third table on page 4. On the other hand, it is a significant circumstance that the glass of the Krakatoa-lavas is sometimes found without the porphyritic crystals; pumice formed of this glass without any enclosed crystals was certainly erupted during the eruption in May, 1883. Similar facts are recorded by Fouqué in the case of the Santorin lavas. It must be remembered, too, that the whole of the lavas of Krakatoa, and perhaps of all the volcanoes on the line of cross fissure upon which it is situated, are of an exceptional character; the ordinary enstatite-andesites of Java containing only about 55 to 62 per cent. of silica, and having a much smaller proportion of glass to the porphyritic crystals. In Santorin, too, we have the same difference, though somewhat less marked, between some of the older and deep-seated dykes and the modern lavas of the volcano.

All of these facts point to the conclusion that after the partial separation of a magma into crystals and a colloid residue, the two may be separated by a process of liquation, and subsequently become mingled again in varying proportions. I need scarcely point out that the condition of many porphyritic crystals—eroded, broken, or frayed out in the magma in which they lie—are strongly suggestive of the same conclusion. These porphyritic crystals indeed have often the appearance of foreign materials which have been caught up by the magma in which they are now found.

It is a significant circumstance that the Krakatoa-rocks, and this is true of many other rocks of the same class, do not appear to have their porphyritic crystals scattered quite at hazard through their mass. On the contrary, the felspars, pyroxenes and magnetite are seen to form little knots often intercrystallized in the midst of the vitreous base. In this respect, there is an approach to the structure for which I have proposed the name of "glomero-porphyritic," in which we find what looks like the association of minerals typical of one class of rock scattered through a rock of a totally different class. In the typical example of the kind which I have described fragments of troctolite appear as if scattered through an ophitic dolerite.

In the case of the plutonic rocks of the Western Isles of Scotland, I have shown how frequently one or other of the constituents of a magma may segregate locally so as to give rise to a variety of rock in which this mineral predominates. In this way gabbros are found graduating in places into rocks essentially composed of olivine, pyroxene, or felspar.

If, as the consideration of these rocks at Krakatoa so strongly suggests, the minerals crystallized out of a magma, and the residuum of mixed silicates can be separated to a greater or less extent, and then recombined in fresh proportions, we have an explanation of the ejection from the same vent of materials differing most widely in their ultimate chemical composition, though presenting curious peculiarities in the enclosed minerals which are common to all of them.

It is almost impossible to study the older and more recent ejections from Krakatoa without being driven to consider the possibility of the latter as having been to a great extent formed by the refusion of the former. Indeed the existence of knots of the unfused black glass in the midst of the modern pumices, and portions of the same material clinging to the crystals embedded in the recent obsidian, seem to render the fact of this refusion all but certain. How this refusion might have been brought about, a few very simple considerations will, I think, enable us to understand.

The late Dr. Frederick Guthrie, whose early death was so great a loss to science, was engaged in a number of researches which have a very important bearing on questions of petrogeny, and are of great suggestiveness to the geologist. Solutions of various salts when cooled down are found to yield successive crops of crystals of ice or of the salt, until at last the remaining mixture of the two substances in a definite proportion are left behind, forming the bodies to which Dr. Guthrie gave the name of *Cryohydrates*. He subsequently showed that mixtures of metals or of salts behave in the same way when reduced to liquid condition by heat, and for those substances, compounds which separate out like the cryohydrates from a solution, he proposed the name of *Eutectic* bodies or *Eutectics*. The chief characteristics of these bodies is the lowness of their temperature of fusion.

Dr. Guthrie himself clearly saw the importance of these considerations to the geologist. We are continually dealing with mixtures of salts (silicates) from which a number of definite crystallized bodies have separated out, till at last a residuum is left which consolidates at a lower temperature than any of them. The determination of the nature and composition of these eutectic silicates is a problem of the very greatest interest to petrologists. In a still later memoir, one of the last which he wrote, Dr. Guthrie attacks a closely related question which is of even greater interest and importance to the geologist. That water plays an important part in the liquefaction of the igneous masses of the Earth's crust has been maintained by Scrope, Scheerer, Bischof, Daubrée, and many other observers, and cannot, indeed, be doubted by any one who has studied the phenomena attending the extrusion of lavas from a volcanic vent. But as to the exact *rôle* played by the water in such molten masses, there has been much difference of opinion, and the researches of Guthrie are of the greatest importance, as throwing new light on this very interesting question.

The influence of the presence of water in lowering the fusion

points of various salts is a question which was very carefully investigated by Guthrie. He showed that a certain mixture of the nitrates of lead and potash had its fusion-point reduced from 3° to 4° C. by the introduction into it of a quantity of water equal to $\frac{1}{55}$th part of its weight. Still more striking are the results obtained by the study of the fusion-point of nitre as influenced by the presence of water. The following table abridged from that given by Dr. Guthrie will serve to explain this subject :—

Fusion-points of Mixtures of Nitre and Water.

Nitre.		Water.		Fusion-points.
100	...	0	...	320° C.
98·86	...	1·14	...	300° ,,
95·11	...	4·89	...	262° ,,
89·94	...	10·06	...	201° ,,
84·69	...	15·31	...	151° ,,
70·14	...	20·86	...	123° ,,
75·02	...	24·08	...	115° ,,
70·03	...	29·07	...	97°·6 ,,

There is no question here of the formation of definite compounds of nitre and water, but in the words of Dr. Guthrie "fused nitre and fused ice are miscible in all proportions," the result of the increase of water being a proportional lowering of the fusion-points. "The phenomenon of fusion" is shown by Guthrie to be "nothing more than an extreme case of liquefaction by solution." Indeed, it is impossible to define where solution ends and fusion begins; when, for example, one part of water is present in 555 parts of a salt, it would be hard to consider the latter as dissolved in the former.

Now it is impossible to doubt for one moment that the presence of water has the same effect on the fusion-points of mixed silicates that it has on other salts, though owing to the high temperatures and pressures required, experiments on these are more difficult than in the case of salts of more easy fusibility. The Zeolites consist of mixtures of silicates of alumina and of the alkalies or lime, in the same proportions as in the Felspars; but while the former contain water, the latter are anhydrous; as is well known, the Zeolites fuse at much lower temperatures than the Felspars. Nor is this true only of definite compounds as is shown by studying the fusibility of such indefinite mixtures of silicates and water as the tachylytes, hydrotachylytes, palagonites, etc.

The consideration of these points leads to a clearer understanding of the method of action of water in volcanic vents. That there are serious objections to the notion of water giving rise to volcanic eruptions by finding its way through *open fissures* to masses of incandescent lava, has been pointed out by Scrope and other authors; and Daubrée and others have advocated the gradual percolation of water through the interstices of solid rock-masses as being an agency more in accordance with the phenomena observed. But it has always been considered necessary to assume a considerable rise in the temperature of the subterranean mass as one of the exciting causes of a volcanic outburst.

A careful consideration of the results arrived at by Dr. Guthrie's

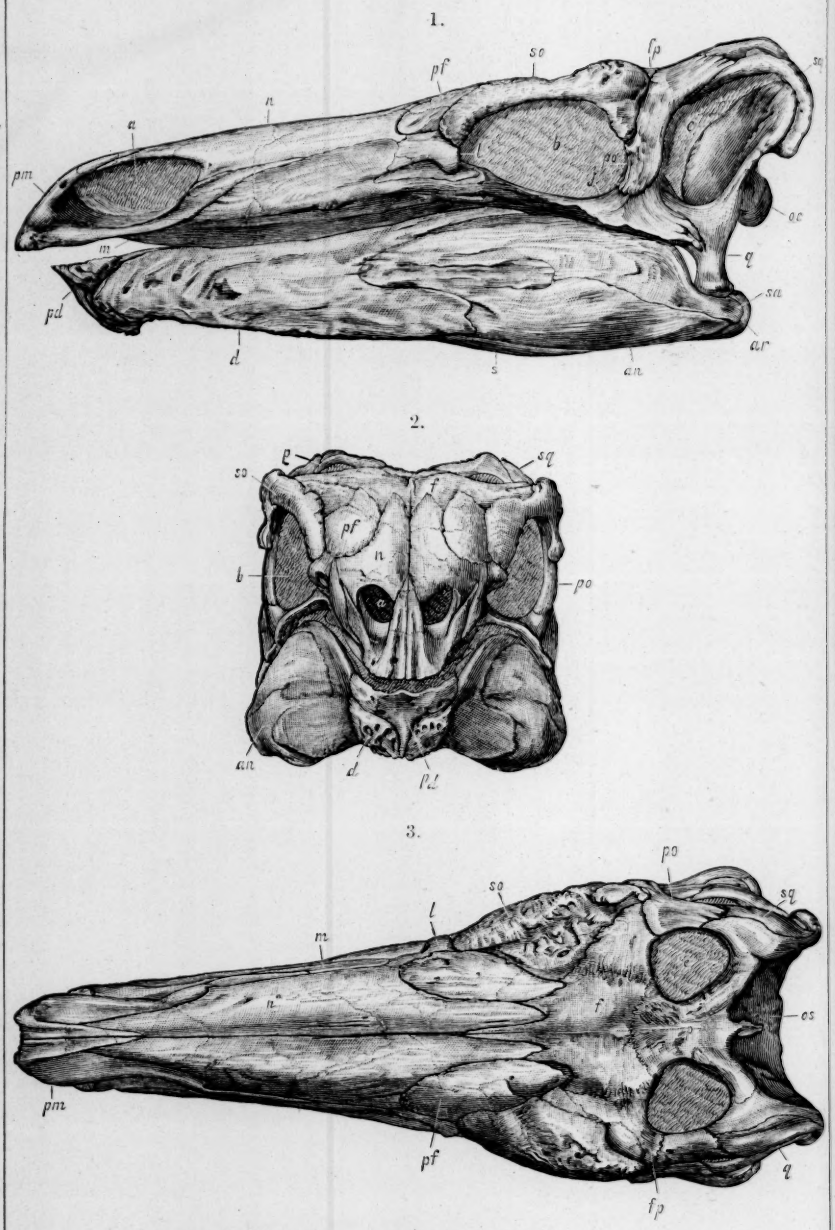


FIG. 1.—Skull of *Stegosaurus stenops*, Marsh; side view.
FIG. 2.—The same specimen; front view.
FIG. 3.—The same specimen; top view.
All the figures are one-fourth natural size.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.

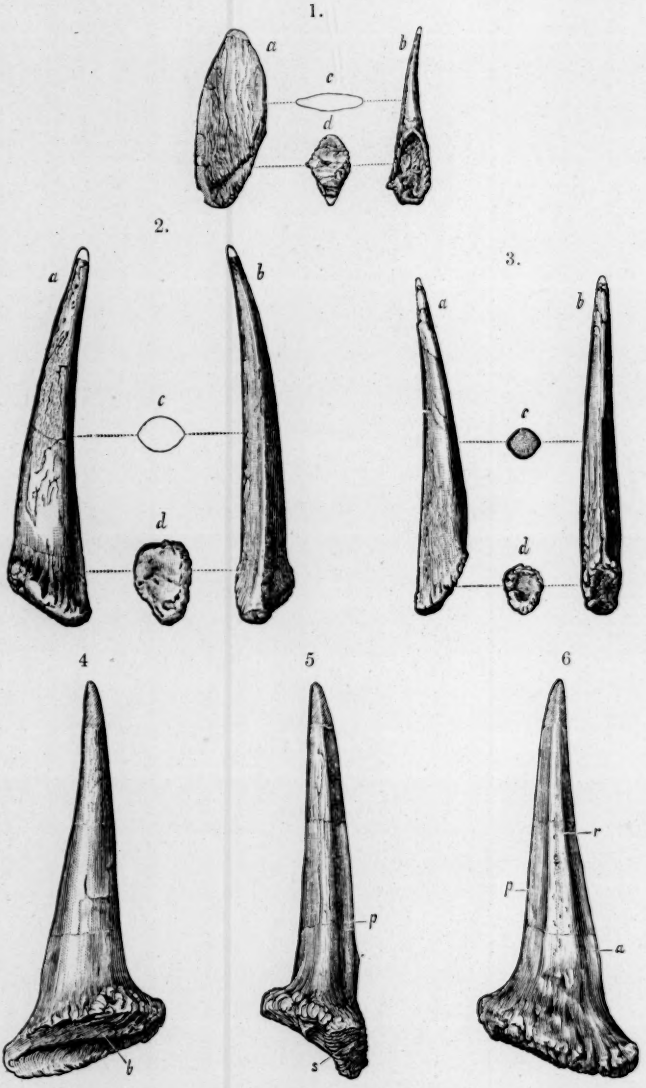


FIG. 1.—Dorsal spine of *Stegosaurus ungulatus*, Marsh; *a*, side view; *b*, posterior view; *c*, section; *d*, inferior view of base.

FIG. 2.—Large caudal spine of same individual; *a*, side view; *b*, front view; other letters as above.

FIG. 3.—Smaller caudal spine of same individual; *b*, posterior view; other letters as above.

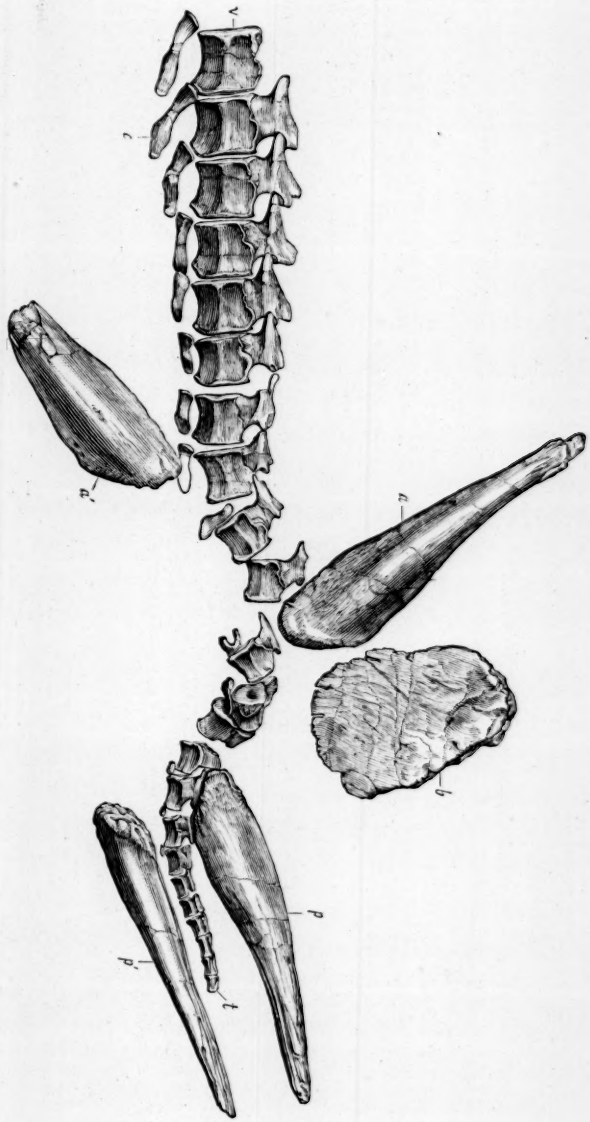
FIG. 4.—Caudal spine of *Stegosaurus sulcatus*, Marsh; side view.

FIG. 5.—The same spine; posterior view.

FIG. 6.—The same spine; inner view.

All the figures are one-twelfth natural size.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.



Caudal vertebræ, spines, and plate of *Diracodon laticeps*, Marsh; seen from the left. One-sixth natural size. *a*, right anterior spine; *a'*, left anterior spine; *b*, small caudal plate; *c*, chevron bone; *p*, right posterior spine; *p'*, left posterior spine; *t*, terminal vertebra; *v*, median caudal vertebra.

From the Atlantosaurus Beds of the Upper Jurassic, Southern Colorado.

researches serves to convince us, however, that such rise of temperature is by no means a necessary prelude to a volcanic outburst, but that the percolation of water to a centre of igneous activity is in itself sufficient to serve as an exciting cause. If we were to imagine a mass of solid nitre lying at some depth within the earth's crust, and having a temperature of 260° C., such a mass would be solid and inert. But if, without raising the temperature, a quantity of water, equal to five per cent. of the weight of the nitre, were introduced into it, then the whole would become liquid and the tendency of the heated water to relieve itself from the pressure might give rise to all the phenomena of a volcanic outburst. What is true of nitre is equally true of the mixed silicates composing lavas, which are at much higher temperatures. The admission of water to such a mass of mixed silicates at a temperature below its point of fusion would cause it to become liquid and thus give rise to the phenomena of eruption. In the case of the Krakatoa-lavas, the anhydrous varieties probably existed quite solid at tolerably high temperatures; but the gradual percolation of water into their mass (and the evidences of such percolation, are seen in the hydrated condition of the minerals composing it) would render the whole liquid, without the necessity for any rise in temperature.

II.—The Skull and Dermal Armour of *Stegosaurus*.

By Professor O. C. Marsh, Ph.D., LL.D.

(PLATES I. II. III.)

In various numbers of the "American Journal of Science," the writer has given the more important characters of the skeleton of the *Stegosauria*, and has indicated the relations of this group to the other known *Dinosauria*.[1] The discovery of additional specimens of *Stegosaurus*, one of them nearly complete, furnishes material to greatly enlarge our knowledge of the skull and dermal covering of this genus, and some of the new facts are given in the present article.

The results of the entire investigation of this group will be brought together in a monograph now in preparation, by the writer, for the United States Geological Survey. The lithographic plates for this volume, sixty-five in number, are nearly all printed, and the figures of the skull here given are taken from these plates.

The Skull. (Plate I.)

The skull of *Stegosaurus* is long and slender, the facial portion being especially produced. Seen from the side, with the lower jaw in position, it is wedge-shaped, with the point formed by the premaxillary, which projects well beyond the mandible, as shown in Fig. 1, Plate I. The anterior nares (*a*) are large, and situated far in front. The orbit (*b*) is very large, and placed well back. The

[1] "American Journal of Science," vol. xiv. p. 513, Dec. 1887; vol. xix. p. 253, March, 1880; vol. xxi. p. 167, Feb. 1881; vol. xxiii. p. 83, Jan. 1882; and vol. xxiv. p. 410, Nov. 1887.

lower temporal fossa (*c*) is somewhat smaller. All these openings are oval in outline, and are on a line nearly parallel with the top of the skull. In this view, the lower jaw covers the teeth entirely.

Seen from above, as shown in Fig. 3, Plate I., the wedge-shaped form of the skull is still apparent. The only openings visible are the supra-temporal fossæ (*e*). The premaxillary bones (*pm*) are short above, but send back a long process below the narial orifice. The nasal bones (*n*) are very large, and elongate. They are separated in front by the premaxillaries, and behind, by anterior projections from the frontal bones. The prefrontals (*pf*) are large, and are placed between the nasals and the prominent, rugose supra-orbitals (*so*). The frontals are short, and externally join the post-frontals (*fp*). The parietals are small, and closely coössified with each other.

Viewed from in front, the skull and mandible present a nearly quadrate outline (Pl. I. Fig. 2), and the mutual relations of the facial bones are well shown. In this view is seen, also, the predentary bone (*pd*), a characteristic feature of the mandible in this genus. The lateral aspect of this bone is shown in Fig. 1.

The teeth in this genus are entirely confined to the maxillary and dentary bones, and are not visible in any of the figures here given. They are small, with compressed, fluted crowns, which are separated from the roots by a more or less distinct neck. The premaxillary and the predentary bones are edentulous.

The present skull belongs to the type specimen of a very distinct species, which the writer has called *Stegosaurus stenops*. The skull and nearly complete skeleton of this specimen, with nearly all the dermal armour in place, were found almost in the position in which the animal died.

This animal was much smaller than those representing the other species of this genus. Its remains were found in the Atlantosaurus beds of the Upper Jurassic, in Southern Colorado. In this geological horizon, all the known American forms of *Stegosauria* have been discovered.

The Dermal Armour.

The osseous dermal covering of *Stegosaurus* was first described by the writer from specimens found associated with several skeletons, but not in place, and hence the position of the various parts was a matter of considerable doubt. Subsequent discoveries have shown the general arrangement of the plates, spines, and ossicles, and it is now evident that, while all the group were apparently well protected by offensive and defensive armour, the various species, and perhaps the sexes, differed more or less in the form, size, and number of portions of their dermal covering. This was especially true of the spines, which are quite characteristic in some members of the group, if not in all.

The skull was evidently covered above with a comparatively soft integument. The throat and neck below were well protected by small, rounded and flattened ossicles having a regular arrangement in the thick skin. One of these ossicles is shown in Woodcut Fig. 1.

The upper portion of the neck, back of the skull, was protected by plates, arranged in pairs on either side. These plates increased in size farther back, and thus the trunk was shielded from injury.

FIG. 1.—Gular plate of *Stegosaurus ungulatus*, Marsh; *a*, superior view; *b*, side view; *c*, inferior view.

From the pelvic region backward, a series of huge plates stood upright along the median line, gradually diminishing in size to about the middle of the tail. One of these is shown in Woodcut Fig. 3.

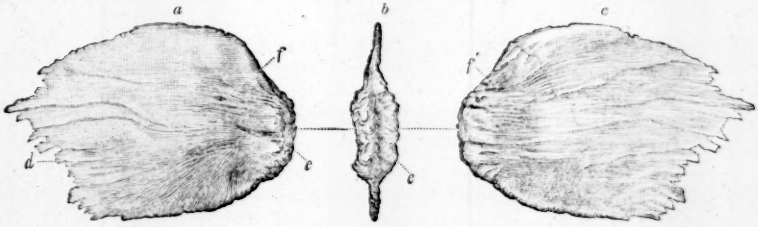


FIG. 2.—Caudal plate of same individual; *a*, side view; *b*, end view of base; *c*, view of opposite side; *d*, thin margin; *e*, rugose base; *f*, and *f'*, surface marked by vascular grooves.

Some of the species, at least, had somewhat similar plates below the base of the tail, and one of these bones is represented in Woodcut Fig. 2.

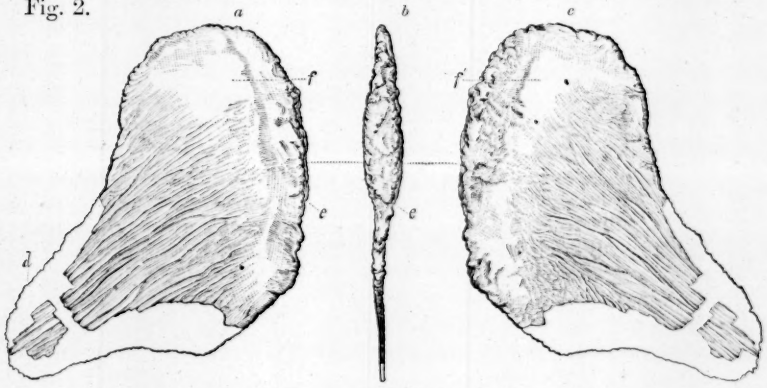


FIG. 3.—Dorsal plate of same individual; *a*, right side; *b*, thick basal margin; *c*, left side; other letters as in last figure.

All the figures are one-twelfth natural size.

The offensive weapons of this group were a series of huge spines arranged in pairs along the top of the distal portion of the tail, which was elongate and flexible, thus giving effective service to the spines, as in the genus *Myliobatis*.

In *Stegosaurus ungulatus*, there were four pairs of these spines, diminishing in size backward. Two of the larger of these are

shown on Pl. II. Figs. 2 and 3. In some other forms there were three pairs, and in *S. stenops* but two pairs have, as yet, been found.

In one large species, *Stegosaurus sulcatus*, there is at present evidence of only one pair of spines. These are the most massive of any yet found, and have two deep grooves on the inner face, which distinguish them at once from all others known. One of these grooved spines is represented on Pl. II. Figs. 4, 5, and 6.

The position of these caudal spines with reference to the tail is indicated in the specimen figured on Pl. III., which shows the vertebræ, spines, and plate, as found.

The American genera of the *Stegosauria* now known are *Stegosaurus*, *Hypsirhophus* and *Diracodon*. Of the former there are several well-marked species besides *S. armatus*, the type. Of the latter genus but one is known at present, *Diracodon laticeps*, the remains of which have hitherto been found in Wyoming at a single locality only, where several individuals referred to this species have been discovered. Aside from the form of the skull, these specimens have in the fore foot the intermedian and ulnar bones separate, while in *Stegosaurus* these carpals are firmly coössified.

All the known American forms appear to have the second row of carpals unossified, and five digits in the manus. In the hind foot, the astragalus is always coössified with the tibia, even in very young specimens, while the calcaneum is sometimes free. The second row of tarsals is not ossified in any of the known specimens. Only four digits in the hind foot are known with certainty, and one of these is quite small. All forms have at least three well-developed metatarsals, which are short and massive, but longer and much larger than the metacarpals. Most of the bones originally referred to the hind foot of *Stegosaurus ungulatus*, and figured as such (Amer. Journ. Sci. vol. xxi. pl. viii.), although found with the posterior extremities, subsequently proved to belong to the fore foot of another larger species.

In one large specimen, of which the posterior half of the skeleton was secured, no trace of dermal armour of any kind was found. If present during life, as indicated by the massive spines of the vertebræ, it is difficult to account for its absence when the remains were found, unless, indeed, the dermal covering had been removed after the death of the animal, and previous to the entombment of the skeleton where found. In this animal, the ilia were firmly coössified with the sacrum, thus forming a strong bony roof over the pelvic region, as in birds.

This specimen represents a distinct species, which the writer has named *Stegosaurus duplex*. It was originally referred by him to *S. ungulatus*, and the pelvic arch was figured under that name.[1] In the sacrum of this species, each vertebra supports its own transverse process, as in the *Sauropoda*, while in *S. ungulatus* these processes have shifted somewhat forward, so that they touch, also, the vertebræ in front, thus showing an approach to some of the *Ornithopoda*.

The great weight of the armour in *Stegosaurus*, taken in connection

[1] Amer. Journ. Sci. vol. xxi. pl. vii. Feb. 1881.

with the massive and solid bones of the skeleton, and, especially, the enormous vertical extent of the compressed tail, indicate an aquatic life. This opinion was expressed by the writer in describing the first specimen found, and the discoveries since made have done much to confirm it. That these reptiles moved freely on land, also, is quite probable. Other genera of the group may have lived mainly upon the land.

The large number of specimens of the *Stegosauria* now known from the American Jurassic, and the fine preservation of some of the remains, enable us to form a more accurate estimate of the relations of the group to the other Dinosaurs, than has hitherto been possible. The presence of a predentary bone, and the well-developed post-pubis, are important characters that point to the *Ornithopoda* as near allies, with a common ancestry. These positive characters are supplemented by some points in the structure of the skull, and the form of the teeth.

There are, however, a large number of characters in which the *Stegosauria* differ from the *Ornithopoda*, and among these are the following:—

(1) All the bones of the skeleton are solid.
(2) The vertebræ are all biconcave.
(3) All the known forms have a strong dermal armour.
(4) The second row of carpals and tarsals are unossified.
(5) The astragalus is coössified with the tibia.
(6) The spinal cord was greatly enlarged in the sacral region.

The relations of these two groups to each other and to the rest of the known *Dinosauria* will be fully discussed by the writer in his monograph on the *Stegosauria*.

New Haven, Conn., *October*, 1887.

III.—On certain anomalous Organisms which are concerned in the Formation of some of the Palæozoic Limestones.

By H. Alleyne Nicholson, M.D., D.Sc., F.G.S.,
Regius Professor of Natural History in the University of Aberdeen.

THAT many of the Palæozoic limestones are more or less extensively composed of the skeletons of various Invertebrate animals, sometimes in a perfect condition, sometimes more or less largely fragmentary, has long been known. In certain instances a microscopic investigation of these ancient calcareous sediments may fail to demonstrate the presence of organic remains, or may reveal but few of these. Thus there occur beds of lithographic limestone in the Palæozoic series which would seem to be simply of the nature of very finely levigated calcareous mud, the component grains of which were, however, doubtless derived, in the first instance, from the calcareous skeletons of animals. Again, it commonly happens, even in examples where the rock may to all appearance be little altered, that a limestone may be found on examination by means of thin sections to have undergone secondary crystallization, with the result of a more or less complete obliteration of the organic remains

of which it was originally made up. Such secondary crystallization is generally the result either of the application to the rock of pressure, or of dolomitisation. In the great majority of the ordinary Palæozoic limestones, it is, however, generally easy to show that the rock is essentially organic, in the sense that it is extensively or essentially composed of the calcareous skeletons of living beings. The organisms which are principally concerned in the formation of the Palæozoic limestones are, as is well known, the Crinoids, the Foraminifera, the Stromatoporoids, and the Corals. Less important, though nevertheless sometimes taking a conspicuous part in the composition of the older limestones, are the Brachiopods, the *Polyzoa*, various groups of Molluscs, and the Ostracodous Crustaceans.

In the present communication I wish to direct attention more particularly to some organisms which are largely concerned in building up certain of the Palæozoic limestones, but which cannot at present be definitely referred to a place in any of the groups of animals above mentioned. The organisms in question are curiously like one another in general form and mode of occurrence, at the same time that they differ entirely in their internal structure; and they have been referred to the anomalous genera *Mitcheldeania*, Wethered, *Solenopora*, Dyb., and *Girvanella*, Nich. and Eth., jun.

Genus Mitcheldeania, Wethered, 1886.

The organisms which compose the genus *Mitcheldeania* have the form of small rounded or oval calcareous masses, made up of capillary tubes, of an oval or circular shape, which radiate from a central point or points, and are intermixed with an interstitial tissue of very much more minute branching tubuli (Fig. 1). The larger tubes may be considered as zoöidal tubes, and the proportion which they bear to the interstitial tubuli varies in different specimens, and in different parts of the same specimen. Usually, the zoöidal tubes occupy comparatively extensive regions of the skeleton, being separated from one another by a limited number of the minute tubuli; the latter also occupying irregular tracts to the exclusion of the large tubes (Fig. 1, A and C). The zoöidal tubes further communicate with one another by means of large irregularly-placed foramina, resembling the "mural pores" of the *Favositidæ* (Fig. 1, G); and they occasionally exhibit a few irregular transverse partitions or "tabulæ." Increase appears to be by fission. The interstitial tubuli communicate with one another by irregular pores in their walls, or by branching, and they constitute a sort of "cœnenchyma," in many respects resembling the cœnosarcal tissue of *Allopora* (see Fig. 1, C).

The genus *Mitcheldeania* was founded by Mr. Wethered (Geol. Mag. 1886, Dec. III. Vol. III. p. 535) for the reception of certain singular little bodies which occur abundantly in parts of the Carboniferous Limestone of the Forest of Dean. The single species recognized was described by Mr. Wethered under the name of *M. Nicholsoni*,[1] and the author was good enough to submit some of his

[1] Mr. Wethered re-described and re-figured the species in the 'Proceedings of the Cotteswold Club,' 1887.

material to me for examination, thus enabling me to prepare for myself a series of thin sections. Owing, however, to its small size and to the minuteness of its component tissues, the investigation of *M. Nicholsoni* is attended with great difficulties; and I have been able recently to make a much more satisfactory study of the characters of the genus from a much larger species, which occurs abundantly in parts of the Carboniferous series of the South of Scotland, and which I shall describe under the name of *M. gregaria*.

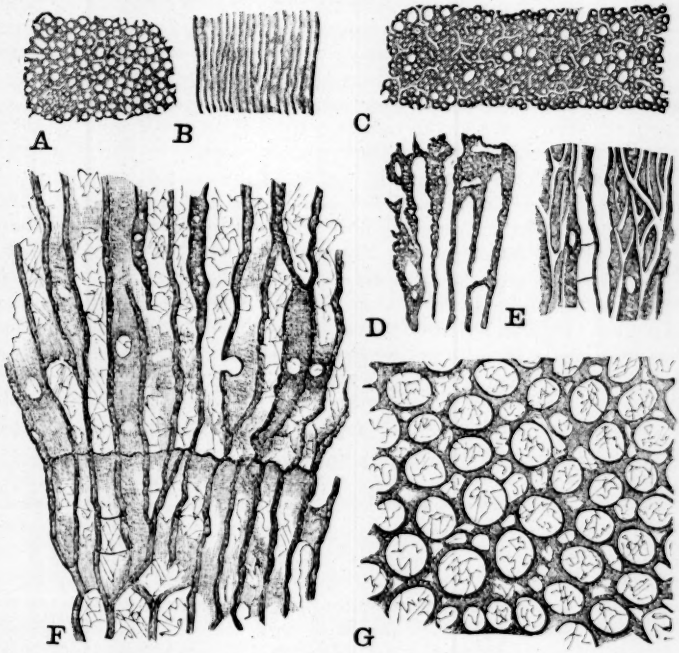


Fig. 1.—Minute structure of the skeleton of *Mitcheldeania gregaria*, Nich. A. Tangential section of part of the skeleton where the interstitial tubuli are comparatively few in number, enlarged 20 times. B. Vertical section of the same, similarly enlarged. C. Tangential section of part of the organism where the interstitial tubules are greatly developed, enlarged 20 times. D. Vertical section of a few tubes, enlarged 40 times. E. Vertical section of zoöidal tubes, with interstitial branching tubuli, enlarged 40 times. F. Vertical section of a part with few interstitial tubes, enlarged 60 times, showing connecting pores and "tabulæ." G. Tangential section of a similar part, enlarged 80 times.

Mitcheldeania gregaria, n. sp. Figs. 1 and 2.

The organism occurs in the form of small rounded masses, approximately spherical in shape, and averaging about 10 millimètres in diameter, some examples exceeding this, while others do not reach this size. There are no traces of a peduncle of attachment, nor do sections exhibit any foreign body which might have served as a nucleus of growth. The surface may be smooth, but is

in general more or less lobulated, exhibiting under a lens, in well-preserved specimens, exceedingly minute pores. The skeleton is composed of radiating capillary tubes, disposed in concentric strata, and having a diameter of from $\frac{1}{12}$ to $\frac{1}{15}$ of a millimètre. In large portions of the skeleton these zoöidal tubes are placed near to one another, being separated only by a single row of smaller tubuli (Fig. 1, F and G), or being in direct contact. In other portions of the skeleton, the large tubes may be absent or may be scattered irregularly among very minute tubuli. These interstitial tubuli (Fig. 1, A and C) have a diameter of $\frac{1}{25}$ of a millimètre, or less, and usually occupy irregular patches of various sizes, between the groups of larger tubes. Vertical sections show that the large zoöidal tubes communicate with one another by oval or circular apertures, of comparatively large size, and uniserially disposed, the general aspect of these resembling that of the "mural pores" of the *Favositidæ* (Fig. 1, F). Very commonly, indeed usually, the zoöidal tubes appear to be free from internal partitions, but transverse plates, resembling "tabulæ," can sometimes be recognized here and there. No structures of the nature of radiating "septa" are present in the tubes. The interstitial tubuli appear to communicate with one another by minute pores; and vertical sections show that they commonly branch irregularly, and anastomose with one another (Fig. 1, E). Hence, in tangential sections of the areas occupied by the tubuli, there are generally seen minute branching canals interspersed among the cut ends of the tubuli, and resembling in aspect the cœnosarcal canals of *Allopora* and *Millepora*, and of many Stromatoporoids (see Fig. 1, C).

This remarkable organism occurs in vast numbers in the Lower Carboniferous Series of parts of the South of Scotland and the North-west of Northumberland, and forms in places extensive beds of limestone. It was first brought under my notice by my friend Mr. Benjamin Peach, who informs me that it has a wide distribution; but the only locality in which I have personally collected it is

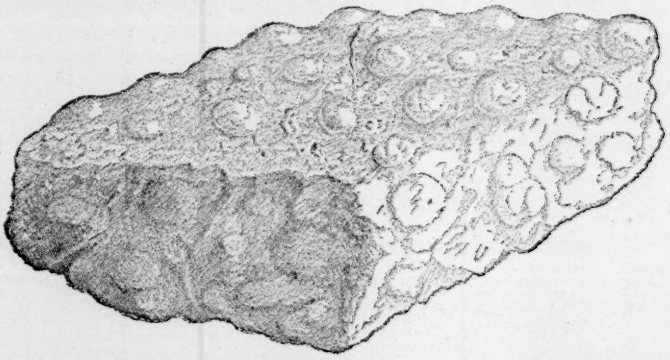


Fig. 2.—A fragment of limestone from the Lower Carboniferous Series of Kershope Foot, largely composed of *Mitcheldeania gregaria*, of the natural size.

Kershope Foot, in Roxburghshire. Here beds of the limestone are more or less extensively composed of the bullet-shaped or grape-like skeletons of this singular fossil (Fig. 2).

There is no room to doubt that *M. gregaria* is congeneric with *M. Nicholsoni*, Wethered, from the Carboniferous Limestone of the Forest of Dean. It is, however, clearly a distinct species, not only being constantly of much larger size, but being also distinguished by marked structural peculiarities. Thus, *M. Nicholsoni* rarely exceeds four or five millimètres in length, and is very irregular in form, commonly enveloping other organisms, or forming crusts on foreign bodies. The zoöidal tubes in this species are also proportionately large in point of size, are few in number and irregular in distribution, and are separated by a great proportionate abundance of minute interstitial tubuli.

Thin sections of *Mitcheldeania gregaria* have a general resemblance to corresponding sections of certain Monticuliporoids, but none of the latter make any approach to the present form as regards the minuteness of the component tubes of the skeleton. The presence of connecting-pores between adjacent zoöidal tubes and of an interstitial canal-system would also separate *Mitcheldeania* structurally from the Monticuliporoids. In spite of the extreme minuteness of its tissues, the genus *Mitcheldeania* may, I think, be referred with tolerable certainty to the *Cœlenterata*. Admitting its Cœlenterate affinities, it would seem almost certain that the genus must be placed in the series of the *Hydrozoa*. There is, however, no known group of this class within which *Mitcheldeania* can be satisfactorily located. Its closest affinities seem to be with the Hydrocorallines, and in this connection I would particularly draw attention to the resemblance of the interstitial tissue of *Mitcheldeania* to the cœnenchymal tissue of certain species of *Allopora*. In one species of the latter genus which I have investigated the cœnenchymal tissue is not only very similar to that of *Mitcheldeania*, but is not so very much grosser in structure. On the other hand, all the known Hydrocorallines possess zoöidal tubes which are enormously larger than those of *Mitcheldeania*; and there are other morphological features in the latter genus which would preclude its being actually placed, with our present knowledge, in the group of the *Hydrocorallinæ*.

Genus Solenopora, Dybowski, 1877.

This genus includes calcareous organisms, which present themselves in masses of varying form and irregular shape, and are composed wholly of radiating capillary tubes arranged in concentric strata. The tubes are in direct contact, and no "cœnenchyma," or interstitial tissue, is present. The tubes are thin-walled, irregular in form, often with undulated or wrinkled walls, without mural pores, and furnished with more or fewer transverse partitions or "tabulæ." No radiating "septa" are developed, but the type-species exhibits more or fewer inwardly directed septiform processes, which are the result of the rapid fission of the tubes (see Fig. 3, C).

The genus *Solenopora* was originally described by Dr. Dybowski (Chætetiden der Ost-Baltischen Silur-Formation, p. 124, 1877) for the reception of a singular fossil which is of common occurrence in the Ordovician limestones of certain localities in Esthonia. The structure of this organism has been fully dealt with by Mr. R. Etheridge, jun., and myself (Geol. Mag. Dec. III. Vol. II. p. 529, Pl. XIII.), and we have shown its identity with the forms previously described by Mr. Billings as *Stromatopora compacta*, and by ourselves as *Tetradium Peachii*. The species stands, therefore, now as *Solenopora compacta*, Billings, the Scotch examples remaining as a variety, for which the name *Peachii* may be employed.

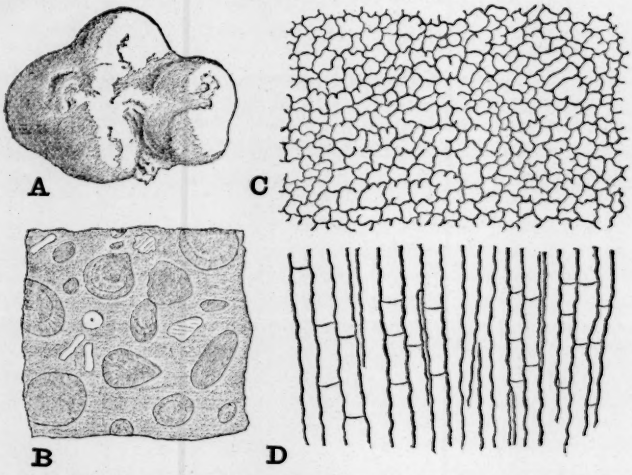


Fig. 3.—A, A small specimen of *Solenopora compacta*, Billings, from Saak, Esthonia, of the natural size. B, Surface of a piece of limestone largely made up of small specimens of the same, from the same locality, of the natural size. C, Tangential section of the same, enlarged about 35 times. D, Vertical section of the same, similarly enlarged.

Solenopora compacta, Billings, sp. Fig. 3.

This species has been so fully treated previously (*loc. cit. supra*), that it is unnecessary for me to enter here into any discussion of its characters. The accompanying illustration (Fig. 3) will sufficiently indicate its general form, mode of occurrence, and minute structure. As a species it is distinguished by the size of its component tubes (which vary in diameter from $\frac{1}{12}$ to $\frac{1}{20}$ of a millimètre), and by the facts that the tubes are irregular in shape, have undulated walls, and are furnished with more or less numerous septiform processes due to fission (Fig. 3, C and D).

It has been already shown by Mr. R. Etheridge, jun., and myself (*loc. cit.*), that *Solenopora compacta*, Billings, is very widely distributed in the Ordovician rocks, and that it played a very important part in the formation of certain of the limestones of this period.

We recognized its occurrence in the Trenton and Black River Limestones of North America, in limestones of corresponding age in Esthonia ("Jewesche Schichten"), and in the Ordovician limestone of Craighead, near Girvan, in Ayrshire. To the facts previously recorded with regard to the range of this remarkable fossil, I can now add some further information of interest. Thus my friend Prof. Lapworth has recently submitted to me a number of examples of this species, of unusually large size, which he has collected in the "Hoar-Edge Limestone" of Shropshire. This discovery has the effect of extending the known range of *Solenopora compacta* in Britain from the Ordovician area of Ayrshire to that of the classical district of the West of England. Again, I find that the fossils described by Mr. S. A. Miller, from the Cincinnati group of North America under the name of *Stromatocerium richmondense* (Journ. Cincinnati Soc. Nat. Hist. vol. v.) are in part referable to *Solenopora*, and are undistinguishable from *S. compacta*, Bill., sp. Mr. E. O. Ulrich has been kind enough to furnish me with a number of specimens from the Cincinnati group of Indiana, which he regards as referable to the so-called *Stromatocerium richmondense*. These specimens are in the form of small irregular calcareous masses, very closely resembling one another in general appearance, but differing so far that, when broken across, some show a conspicuous composition out of concentric layers, while others are more compact and uniform in texture. In point of fact, the specimens, in spite of their apparent similarity, are not all the same. Some of them are referable to *Solenopora compacta*, Bill.; others are referable to a species of *Girvanella* (= *Strephochetus*, H. M. Seeley); while others are composed of both these organisms growing in superimposed colonies.

SOLENOPORA? FILIFORMIS, n. sp. Fig. 4.

In the Ordovician limestone of Craighead, near Girvan, there occurs a fossil which I may provisionally describe under the above name, and which is associated with the preceding in the formation of the limestone. It is often present in great abundance in the limestone, but its internal structure is commonly much obscured, or even destroyed by crystallization. It presents itself sometimes in the form of small rounded or irregular nodules, or, at other times, as lobate or ramified masses of considerable dimensions. Viewed with a powerful magnifying glass it appears to be quite compact, or obscurely fibrous; but when examined microscopically, it is seen to be composed of exceedingly minute capillary radiating tubes disposed in concentric strata. The tubes are thin-walled, regularly prismatic in shape, without mural pores or radiating septa, but furnished with numerous transverse partitions or "tabulæ" (Fig. 4). The average diameter of the tubes is about $\frac{1}{2\frac{1}{4}}$ of a millimètre. Increase of the tubes appears to take place by fission, but the tubes do not exhibit inward septiform processes, such as are so characteristic of the cross-sections of the tubes of *Solenopora compacta*.

I have some doubts about the reference of this fossil to the genus

Solenopora, as it differs from the type of the genus in important structural characters. This is more particularly seen in the regularly prismatic form of the component tubes of the skeleton, and in the total absence of the septa-like process produced in *Solenopora compacta* by the commencing fission of the tubes. At the same time, it agrees entirely with *S. compacta* in its general form and mode of occurrence, and especially in its being composed of imperforate, tabulate tubes of excessive minuteness. Upon the whole, therefore, it seems safest to place it temporarily in the genus *Solenopora*.

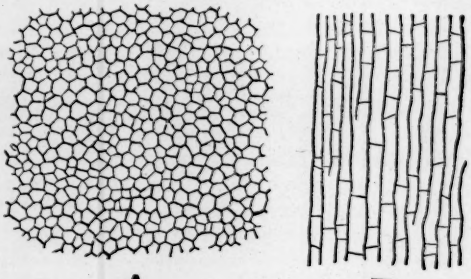


Fig. 4.—A, Tangential section of *Solenopora* ? *filiformis*, Nich., from the Ordovician limestone of Craighead, Girvan, enlarged about 60 times. B, Vertical section of the same, similarly enlarged.

It cannot be said that the present species throws much fresh light upon the systematic position of the genus *Solenopora*. If viewed without reference to the *size* of its tubes, it might quite well be regarded as a *Monticuliporoid*, and might be placed under the genus *Monotrypa*. The extraordinary minuteness of the tubes would seem, however, of itself, sufficient to preclude a reference of this fossil to the Monticuliporoids. If, however, we admit that the genus *Mitcheldeania* may be referred to the *Hydrozoa*, we can get over one of the principal difficulties attending the supposition that the genus *Solenopora* is referable to the same great class—the difficulty, namely, that no known Cœlenterate possesses a skeleton of such an excessively minute character. Upon the whole, therefore, I am inclined to think it may be tolerably safe to regard *Solenopora*, Dyb., as representing a peculiar extinct group of *Hydrozoa*, though I do not think that the evidence upon this point is in any way conclusive.

Genus Girvanella, Nicholson and Etheridge, Jun., 1880. Fig 5.

Largely concerned in the formation of the Ordovician limestones of Ayrshire, and commonly associated with the preceding, is another remarkable organism which was described in 1880 by Mr. R. Etheridge, jun., and myself, under the new generic and specific name of *Girvanella problematica* (Mon. Sil. Foss. Girvan, p. 23, pl. ix. stone at Craighead, sometimes being the principal agent in the fig. 24). This curious fossil occurs in great numbers in the lime-formation of the rock, and presents itself in the form of small

rounded or irregular nodules, which vary in diameter from less than a millimètre to more than a centimètre. The larger examples (Fig. 5, A) show a distinctly concentric structure, visible even to the naked eye, but the most powerful lens fails to show any obvious internal structure in fractured or weathered surfaces. Examined microscopically by means of thin sections, the nodules of *Girvanella* are seen to consist of exceedingly minute circular tubes, endlessly contorted and bent, and twisted together in loosely reticulate or vermiculate aggregations (Fig 5, B). The tubes vary in their size from $\frac{1}{25}$ to $\frac{1}{60}$ of a millimètre in diameter. Most commonly they are about $\frac{1}{45}$ mill. in diameter. The walls of the tubes have a granular aspect, as if formed of exceedingly minute granules, but it is not possible to determine absolutely whether they are or are not truly calcareous in composition. No internal partitions are visible in the tubes, nor do they exhibit any perforations in their walls.

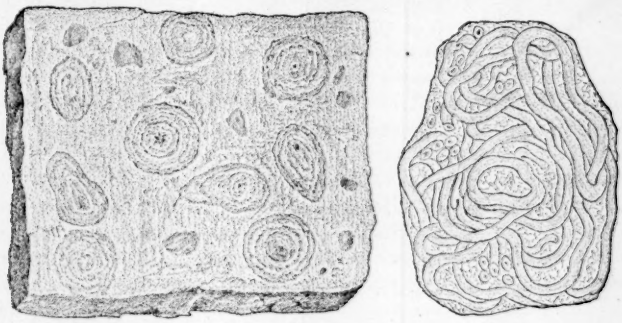


Fig. 5.—A, Fragment of limestone from the Ordovician rocks of Craighead, Girvan, of the natural size, showing numerous exceptionally large masses of *Girvanella problematica*, Nich. & Eth. jun. B, Section of a minute mass of *Girvanella*, enlarged about 60 times.

In the original description of *Girvanella problematica* by Mr. R. Etheridge, Jun., and myself (*loc. cit.*), the genus was provisionally referred to the *Rhizopoda*, and was regarded as related to the arenaceous *Foraminifera*. This view of the affinities of *Girvanella*, from which I see no reason to depart, was the one taken by Mr. H. B. Brady, to whom we had submitted our specimens; and this distinguished authority compared *Girvanella* with the recent *Hyperammina vagans*, figures and descriptions of which have now been published (see Chall. Reports, vol. ix. p. 260, pl. xxiv. figs. 1-9). The same author's great work on *Foraminifera* contains, however, another genus of arenaceous *Foraminifera* which admits, perhaps, of an even closer comparison with *Girvanella* than does the form above mentioned. I allude to the remarkable form described by Mr. Brady under the name of *Syringammina fragilissima* (Chall. Reports, vol. ix. p. 242, woodcut), in which the organism is free, and consists of a mass of minute arenaceous tubes disposed in concentric layers, and having a generally radiate arrangement.

In Britain, the genus *Girvanella* has, so far, only been recognized as occurring in the Ordovician limestones of Ayrshire. I have, however, found some of the Carboniferous limestones of the North of England to contain largely an ill-preserved organism which will, I think, prove to be referable to *Girvanella*. As previously pointed out, the genus occurs in the Ordovician rocks of North America. This is shown by the fact that certain of the specimens from the Cincinnati Group of Indiana sent to me by Mr. E. O. Ulrich as belonging to the *Stromatocerium richmondense* of Mr. S. A. Miller, prove on examination to belong to a species of *Girvanella*, specifically distinct, I think, from our British species, as shown by the greater minuteness of its tubes. I see, also, no reason to doubt that the fossils from the Chazy Limestone of North America, for which Prof. Henry M. Seeley has proposed (Amer. Journ. Sci. and Arts, 1885, vol. xxx. p. 355, 1885) the new generic name of *Strephochetus*, are in reality referable to the genus *Girvanella*. It is probable that the Chazy form (*Strephochetus ocellatus*, Seeley) is *specifically* distinct from *Girvanella problematica*, but its *generic* identity appears to be indubitable.[1] Prof. Seeley seems disposed to think that the curious fossil described by Prof. James Hall, from the Calciferous Limestone, under the name of *Cryptozoön proliferum* (Thirty-sixth Ann. Rep. of the State Cabinet, pl. vi. 1884), may be related to *Girvanella*; but I cannot think that such a relationship—supposing it to exist—can be one of generic affinity. The fossil for which Prof. Hall has proposed this name is not only comparatively gigantic in point of size, but its internal structure, so far as may be judged from the incomplete provisional diagnosis given by its author, is altogether different, since it is stated to consist of branching and anastomosing canaliculi. Lastly, with regard to Prof. H. M. Seeley's reference of *Girvanella* (=*Strephochetus*) to the calcareous sponges, it need only be said that the structure of the genus, so far as recognized, shows nothing which would warrant such a reference, and that it would be essential to the establishment of this view, according to our modern lights, that the organism should be proved to possess definite spicules.

IV.—Hertfordshire Subsidences.

By A. C. G. Cameron.

SUBSIDENCES are by no means unusual amongst the arable lands in the Chalk districts of this county. No one, who has travelled in these parts, can have failed to notice the numerous holes and dells dotted about the fields in all directions, many of which have fallen in, or will do so, in course of time. Nearly all of them mark spots where the Chalk has been dug up for chalking the land, which is then said to work better.[2]

On the crown of some hill or ridge, it is no uncommon sight to

[1] Dr. Hinde has already pointed out that *Strephochetus*, H. M. Seeley, is identical with the previously described *Girvanella*, and has further shown that the *Siphonema* of Dr. Bornemann, supposed by its describer to be a calcareous Alga, is likewise a synonym of *Girvanella* (Geol. Mag. 1887, Dec. III. Vol. IV. p. 227).

[2] Gravel soils, such as fringe the modern alluvium of rivers and streams, are chalked as well as the stronger soils.

find a windlass and bucket erected over a circular hole or shaft sunk deep in the Chalk, while a man at the bottom, working right and left of him, sends bucketfuls of dazzling, white chalk to the surface, which is wheeled away in barrows, and deposited in heaps close to one another, in the field where the shaft has been sunk, to be afterwards broken up, and lain about the place.

When all the chalk that is required has been dug up, the windlass disappears, and the hole is filled up to the original surface level, in order that no unnecessary unevenness should occur to mar the ploughing. Gradually however, a subsidence takes place, as the material, with which the hole was filled, settles down in the cavity prepared for it, and then for a time, a basin-shaped hollow marks the site of the shaft. Suddenly a deep ring-like orifice, the sides of which show a clear section of the earth and stones, with which the hole was filled, appears at the bottom of the pit, and a veritable swallow-hole is formed on the spot.

If it is only a subsiding hole, that is, one that may go down at any moment, a short funnel or pipe is seen, without the ring-like orifice and clean cut sides.

Harvest is the time, I am told, when these pits most frequently fall in; but as the subsidences also occur during rainy seasons, when water wells up or accumulates at the bottom, I am inclined to think the reported falling in at harvest time is greatly accounted for by reason of more people being in the fields then to observe them than at any other time. Holes are being re-filled this autumn about here, that have required filling several times before.

In some parts of the county "doming" is resorted to for covering the holes, thereby obviating the periodical filling up, which may require doing yearly. A pit to be domed, is first nearly filled up to the original surface-level, at least presumably so—and then arched over with brickwork and covered with earth. This plan is said to cost no more than the other, but the latter is the safer of the two.

A labourer informed me that somewhere in the Baldock country, a domed hole once caved in when a ploughman and lad with three horses were crossing it. The two attendants had a narrow escape for their lives, the three horses were killed. Poles are sometimes put up to show the sites of these pits.

The foregoing brings to my recollection much that is in common with the 'natural pits' at Ripon,[1] where it will be remembered a haystack disappeared down a cavity[2] that suddenly opened in the limestone, during the time the haymakers had adjourned for dinner. Doubtless some Hertfordshire subsidences[3] are as natural as those at Ripon—due to the dissolution of the strata by acidulated waters.

Semicircular holes in the chalk filled with brickearth, often seen

[1] See Natural Pits at Ripon, by Rev. Stanley Tute, Proc. Yorks. Geol. and Polyt. Soc. 1869. Also 'Subsidences over Permian Limestone,' A. C. G. Cameron, Rep. Brit. Assoc. York, 1881, and Proc. Yorks. Geol. and Polyt. Soc. vol. vii. pt. iv.

[2] Locally named "shoots" and "earthquakes."

[3] See "Nature," vol. xxxvii. Dec. 8, 1887, On an Earthquake in England, by Worthington G. Smith.

where any considerable section of Chalk is exposed, as in a rail or road cutting, indicates natural subsidences whose origin may be traced to causes similar to those at Ripon.

If it were possible to see the surface of the Chalk, bared of its superficial covering of clay, loam, etc., it would, I imagine, be singularly convex and concave. In digging pits, the chalk is is sometimes found close to the surface at one side of the shaft, but cannot be found at twenty or even thirty feet on the other side.

V.—Effects of Alternations of Temperature on Terra Cotta Copings set in Cement as an Illustration of a Theory of Mountain Building.

T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

ELSEWHERE I have shown that metals under certain conditions when subjected to changes of temperature undergo permanent deformation. Thus sheets of lead ridge up and fold even under the influence of atmospheric changes, as may be seen by the examination of any old lead flats or gutters. The cumulative effect of small but repeated changes of temperature is very striking, and I have used it in illustration of what I conceive to be the true explanation of the ridgings up of the earth's crust called mountain ranges. The examples given[1] of the effects of alternations of temperature are mostly in metals, but I have also shown that other materials not ductile are affected in the same way, in a lesser degree.

A very remarkable example has lately come under my notice[2] of the lengthening of a terra cotta coping, which it appears to me can only be explained on the same principle.

The coping in question which, is freely exposed to the direct rays of the sun, consists of two courses of red Ruabon terra cotta bricks set in cement upon a fence wall, built with common bricks in mortar a brick and a half thick. The courses are level, but, in consequence of the inclination of the road, the coping is stepped down at intervals, so that the under-course of bricks of one length is just gripped and held in position by the top course of the next length of coping. It will thus be seen that it must constitute by liability to lifting a more delicate test than ordinary of any increase of length that might take place in the coping.

When I examined the coping—and I have looked at it over and over again—the end portion of one length abutting against the next length at the drop in the level was thrown up into an anticlinal of about 6 ft. span ; the coping bricks being lifted in the highest part one inch from their bed. There was a fracture at the crown of the anticlinal, and another at the foot or springing, but for a distance of 30 feet the coping was practically one solid continuous bar. A careful examination showed that the coping had "grown" about a quarter of an inch longer than when it was first set, and that this

[1] Origin of Mountain Ranges, chap. iii. and iv.

[2] I am indebted to Mr. F. Archer for first calling my attention to it.

lengthening, as shown by movement on the corbel bricks which occur at intervals, was evenly distributed along a length of 30 feet.

One of the first explanations that occurred to me was that the lengthening was due to the expansion of the cement, as we know that cement if used too soon does expand for a certain length of time after setting.[1] Enquiry from the builder, Mr. Bates, who put up the wall, showed this not to be a probable explanation, as the wall was built some seven years ago. Mr. Bates informed me that he reset the end bricks of this portion of the coping, about two years after the wall was built, in consequence of its lifting, and I have ascertained that Mr. Taylor, a bricklayer, has reset it on two occasions when it lifted from the same cause, first on May 9th, 1884, and secondly on May 16th, 1885. He has now just reset it for a third time.

An inspection of brick copings in the neighbourhood of Blundellsands, of which there are many, disclosed the fact that this is not a solitary phenomenon. In another case where the coping is of blue Staffordshire bricks, the top course in cement and the under-course in mortar, a change in length is shown clearly by the coping being lifted off the wall at each of the two ramps (curved changes of level) which exist in its length, and the movement can be clearly measured on the corbel bricks as before, and in this case the lengthening is also a quarter of an inch, evenly distributed over a considerable length of coping.

Numerous other examples are to be seen, which, though not so striking as those described, clearly evince a movement of the copings.

It will no doubt be considered a long step from brick copings to mountain-building, but as a good example of the permanent lengthening that may take place as the accumulated result of small movements of expansion by change of temperature in what appears to be an intractable material, the facts are well worthy of record. It appears that when the ends of a coping such as I have described butt up against a solid pier, this movement does not take place probably from the elasticity of the material being sufficient to absorb whatever small expansions may occur.[2] When one end is partially free to move, the effect is different, each expansion, however small, pushing the coping along towards the partially free end, and on contraction the coping cannot draw itself back to the same position as before, so must either fracture or lengthen by increments, and experience shows that is what frequently happens.

[1] In order to ascertain precisely whether any alteration of length does take place in cement, I had a bar made composed of one of best Portland cement to one of fine sand. In this bar were fixed brass studs for measuring purposes. On Sept. 1st, three weeks after it was made, the bar measured 16·136 inches between the studs. On Nov. 6th it measured 16·122 inches, showing a *shrinkage* of 0·014 of an inch, and the contraction has not yet ceased.

[2] Since this was written I have observed several cases in which the end brickwork and piers have been badly fractured by the force of expansion.

VI.—British Upper Tertiary Corals.

By Alfred Bell.

WRITERS on Fossil Corals seem to ignore the existence of Corals in our later Tertiary formations. They are certainly not common. The following reference and species have come under my notice: *Caryophyllia clavus, Scacchi* var. *borealis*, Flem., Lancashire drift (see Geologist, 1843, p. 124). *Caryophyllia clavus* var. *Smithii*, Stokes, Raised beach, Portrush, Co. Antrim (Portlock, Geol. Londonderry, etc.). *Sphenotrochus Wrightii*, Gosse, from the Clyde beds, by Messrs. Crosskey and Robertson. To these I may add a fine calice of the Norway branching Coral *Lophohelia prolifera*, Ed. and H., from the interglacial sands of King Edward, N.B., and a single young example of *Sphenotrochus Macandrewanus*, E. and H., from the Raised sea-bed, Largo Bay, Fife.

Two species occurring in the disturbed portion of the Suffolk Red Crag appear to be of Diestien origin, viz. *Solenastrea Prestwichii*, Dunc., present in beds of that age in Belgium (Brussels Museum), and a stout form of *Flabellum*, whose affinities are rather to *F. appendiculatus*, Nyst, than to *F. Woodii* of the Coralline Crag, to which it is commonly referred. I judge this after an examination of a large number of specimens of the different species—mostly worn and rolled examples.

The "Reed Coll.," York Museum, contains a minute *Sphenotrochus* not more than $\frac{1}{16}$ inch in height, which I obtained from the well-known Chillesford Sands at Aldeby. I have only seen this one example, and have, pending further discoveries, given it the trivial name of *S. parva*.

The Crag *Sphenotrochi* would probably repay further examination, as in several instances I have noticed that the costæ instead of presenting the usual strait parallel arrangement, sometimes wavy at the lower end, are strongly wavy, the projections interlocking one within the other

P.S.—Since writing the above Mr. Tomes, F.G.S., has kindly examined the corals referred to in the last paragraph, and describes them as follows:—

Sphenotrochus Boytonensis, Tomes, n.s.

The corallum is of equal breadth for the whole of its height, but it is very thin at the base. The curve of the margin of the calice in the long direction is about the same as in *Sphenotrochus intermedius*. The long diameter of the calice to the short one is as 6 to 4. There are twenty-four septa and the primary and secondary ones are united to the columella by trabiculæ, which are not in pairs, but are single. A few large papillæ appear on the sides of the septa, which have also horizontal ridges ending in simple blunt teeth on their inner margin. These with the growth of the corallum are elongated inwards and become trabiculæ, and are attached to the columella. The latter part as in *Sphenotrochus intermedius* is notched in the middle. The costæ are very uniform in size over the whole of the

corallum, and they are all strongly crispate[1] on every part of it. Height of the corallum 7 lines; greater diameter of the calice, 3 lines, its smaller diameter 2 lines.

The greater size of this species, its remarkable costæ, and the ridges on the sides of the septa will distinguish it. In the nature of the costæ, though in no other respect, it bears some resemblance to *Sphenotrochus crispus*.

The ridges across the septa ending internally in trabiculæ are very peculiar, and give to the latter a greater degree of importance than they would otherwise have.

Localities.—Coralline Crag, Oxford; Red Crag, Boyton, Suffolk; Walton-on-the-Naze, Essex.

NOTICES OF MEMOIRS.

I.—On the Migrations of Pre-Glacial Man. By Henry Hicks, M.D., F.R.S., F.G.S.[2]

REFERRING to the further researches carried on, this summer, at Cae Gwyn Cave, North Wales, which is 400 feet above sea-level, the author stated that the additional evidence obtained proved most conclusively that the flint implement found there last year in association with the remains of Pleistocene animals was under entirely undisturbed Glacial deposits. He maintained also that the evidence is equally clear in regard to the implements found within the caverns, which he said must have been introduced before marine action disturbed the contents of the caverns and the Glacial deposits blocked up and covered them over. The question as to the direction from which pre-Glacial man reached this country is an exceedingly interesting one, and seems now to be fairly open to discussion. It is admitted to be fraught with difficulties, but the facts recently obtained seem to require that an attempt should be made to unravel it. The evidence, so far as it goes, points to a migration to this country from some northern source, as the human relics found in the caverns, and also in the older river gravels (which Prof. Prestwich is now disposed to assign also to the early part of the Glacial epoch, when the ice-sheet was advancing), occur in association with the remains of animals of northern origin, such as the Mammoth, Rhinoceros, and Reindeer. Up to the present no human relics have been found in this country (and it is very doubtful whether they have been found in any other part of Europe) in deposits older than those containing the remains of these northern animals. If man arrived in this country from some eastern area, it is but natural to think that he would have arrived when the genial Pliocene climate tempted numerous species of Deer of southern origin, and other animals suitable as food for man, to roam about in the South-east of England.

[1] I borrow this descriptive word from MM. Milne Edwards and Haime, but it would be almost better to say that they are zigzag or serpentine.

[2] Abstract of Paper read in the Anthropological Section of Brit. Assoc. Manchester.

Hitherto, however, not a relic has been found to show that man had arrived in this country at that time. But in the immediately succeeding period, with the advent of cold conditions and of the northern animals, evidences of his presence become abundant.

Whether man at an earlier period migrated northward from some tropical or sub-tropical area, where he could have lived on fruit and such like food, there is no evidence at present to show; but it seems certain that the man of the Glacial period in this country lived mainly on animal food, and that he found the Reindeer to be the most suitable to supply his wants. He followed the Reindeer in their compulsory migrations, during the gradually increasing Glacial conditions, and kept mainly with them near the edge of the advancing ice.

II.—On the Discovery of Carboniferous Fossils in a Conglomerate at Moughton Fell, near Settle, Yorkshire. By Robert Law, F.G.S., and James Horsfall.[1]

After briefly noting the various exposures of the conglomerate, its unconformability with the Silurian rocks, its nature, probable age, and the circumstances which led to the discovery of fossils in it; the authors described the following section exhibited on the south-west side of Moughton Fell.

a. Scar Limestone, of light grey colour and well jointed; layers very distinct in lower parts and almost horizontal, the genus *Bellerophon* being the commonest fossil in the lowest bed of this rock. Thickness from 300 to 500 feet.

b. Conglomerate.—Of a bluish-grey colour when newly fractured, and becoming reddish on exposure to the air. The fragments are rounded, angular, and sub-angular in form, consisting of slate, grit, flagstone, and vein-quartz, all apparently derived from Silurian rocks. Fossil shells and corals are common throughout the bed. *Bellerophon*, *Euomphalus*, *Syringopora* and *Lithostrotion* are the prevailing genera. Thickness from 1 to 12 feet.

c. Lower Silurian slates, of great thickness, having a N.E. strike and a dip of about 65°. The dip and cleavage appear to be on the same plane in this locality.

The nature and the origin of the stones in the conglomerate were next pointed out; also it was shown that the portion of the bed in which fossils had been found was not more than 200 yards in length, and that it was thickest in the middle, thinning out to the east and west, and at one point could be seen merging into the overlying limestone.

The fossils collected from the conglomerate are as follows:—

Syringopora ramulosa.
Lithostrotion basaltiforme.
Euomphalus pentangulatus.
Cirrus, one species.
Sanguinolaria angustata.
Pleurotomaria, one species.
Orthoceratite, one species.
Rhynchonella acuminata.
Bellerophon tangentialis.
Bellerophon cornu-arietis.
Natica plicistria.
Natica lirata.
Natica elliptica.
Inoceramus, one species.
Spirifera, one species.
Pecten, one species.
Productus, three species.
Leptæena, one species.

In conclusion, attention was called to the probable method by which the conglomerate was formed.

[1] Abstract of paper read before the Geological Section of British Association, Manchester, 1887.

REVIEWS.

I.—Memoirs of the Geological Survey. England and Wales. The Geology of Part of East Lincolnshire. By A. J. Jukes-Browne, F.G.S. 8vo. pp. 181, with 25 Woodcuts and a Plate of Sections and Map (London, 1887.)

THIS memoir treats of the geology of the country near the towns of Louth, Alford, and Spilsby, and is the official Explanation of Sheet No. 84 of the Geological Survey Map of Great Britain. In a concise introductory note the Director-General tells us that the district of which the geology is here described is the southern half of the Wolds, north of the Wash; and that the Memoir gives (1), a detailed account of the various Formations from the Kimeridge Clay to the top of the Middle Chalk. (2.) The subdivisions established by Professor Judd among the Lower Cretaceous (Neocomian) rocks of Lincolnshire have been adopted by the Geological Survey, as well as his name of "Tealby Beds" for the Middle Division of that series. The name of "Spilsby Sandstone" is proposed for the Lower Division. The Upper Group, or "Carstone," here generally consists of mere loose sand. The several subdivisions of the Chalk in this region are now for the first time compared with those which have been worked out by the Survey in Buckinghamshire and Cambridgeshire. (3). A full description is likewise given of the Glacial Deposits which occupy the lower grounds flanking the Wolds; but for his theoretical views, which are not always in accord with those of his colleagues, the author of the Memoir is himself responsible. In connexion with the superficial deposits, he has discussed the comparative age of the several valley-systems of the district. (4). Among the facts of economic importance described in the Memoir is the discovery of two horizons of ironstone and also a seam of phosphatic nodules. (5). A large number of well-sections bearing on the subject of Water-supply are given in the Appendix.

A general description of the geological structure and the physical characters of the district is first given, with lists of the heights, and some sections (pp. 1–8). The Kimeridge Clay is then described (pp. 9–12). The so-called Neocomian Series (pp. 13–27) begins with a nodule-bed on the Kimeridge Clay and at the base of the Spilsby Sandstones, which latter alone the author refers to the *Neocomian* of the Continent, whilst others make it the lower part of that series. The nodules consist largely of rolled fossils, difficult to determine, but for the most part derived from older beds, probably Kimeridgian (p. 18), but possibly Neocomian (p. 139).

The sandstone has large calcareous, fossiliferous concretions in it; and the fossils comprise both Oolitic and Neocomian forms, indicating an intermediate stage between the two systems (p. 141).

Then follows the variable Hundleby Ironstone, equivalent to that at Claxby, and forming the base of the Tealby Clay. This ironstone is a ferruginous loam with oolitic grains of iron-oxide; and the facies of its fossils "is characteristically Neocomian" (p. 141).

The "Tealby Beds" are (1) the ironstone above mentioned; (2)

clays with thin sandstones, septarian nodules, selenite, and pyrites; (3) the "roach," a ferruginous marl with oolitic grains. The clays and the nodules near their base give fossils of an "eminently Neocomian" character. The sands representing the "Carstone," or Upper Neocomian of the district (pp. 23–27), have few fossils, but many phosphatic nodules.

The Upper Cretaceous of Lincolnshire (pp. 28–70) consists of the Lower Chalk and the Middle Chalk; and this begins with (1) the Red Chalk (overlying the Carstone Sands); and this is succeeded by (2) the "Inoceramus-beds," (3) the "zone of *Holaster subglobosus*," and (4) a "shaly marl." Next above comes (5) "hard rocky chalk," making the base of the Middle Chalk, followed by (6) "Chalk with flints and *Inoceramus Brongniarti*." In Cambridgeshire the equivalents of these divisions are—for part of 1, 2, and part of 3, the "Chalk-marl," or "zone of *Rhynchonella Martini*"; for part of 3, the "Totternhoe Stone"; for the rest of 3 and 4, a similar zone and shaly marl; for 5, the "Melbourn Rock" and the "zone of *Rhynchonella Cuvieri*"; for 6, the "zone of *Terebratulina gracilis*," which is succeeded by the "zone of *Holaster planus*," and then by the "Chalk-rock," neither of which members of the Middle Chalk appear in Lincolnshire (p. 30 and footnote). The relative value of these divisions is discussed; the details of their thicknesses, characteristics, and chemical constitution, and palæontology are carefully explained, as well as their sections, exposures, and surface-features. Six woodcuts and several tables illustrate this chapter; and the fossils are tabulated and noted at pp. 142–147.

The Glacial Deposits (pp. 71–101, with woodcut sections, figs. 11 to 19) are described in detail as the "Older" and the "Newer Boulder-clay;" and the Post-glacial Deposits (pp. 102–112), as (1) the "Revesby Gravel"; (2) the Marsh and Fen Deposits; and (3) Blown sand. All of much interest, both locally and generally.

Chapter IX. (pp. 113–131), treating of the hills and valleys of the Wolds, is an explanation of the physical features of East Lincolnshire, worked out *con amore*, carefully written, and well illustrated with plans and sections. Amateurs as well as specialists must derive a real scientific pleasure in following Nature's progressive handiwork in rendering this part of the East of England what it now is.

The *Economics* and *Water-supply* are very well calculated to serve the country. A useful Index and good plate of sections complete this valuable Memoir.

II.—Die Bryozoen der weissen Schreibkreide der Insel Rügen von Th. Marsson. Mit 10 Tafeln. Band 4, Heft 1, 1887. 4to. pp. 1–112. Palæontol. Abhandl. herausgegeben von Dames und Kayser.

TO Dr. Marsson of Greifswald palæontologists are already indebted for two beautifully illustrated memoirs on the Foraminifera,[1] Cirripedia and Ostracoda of the White or Upper

[1] Mittheil. des naturwiss. Ver. für Neuvorpommern u. Rügen in Greifswald. Zehnter Jahrgang, 1878, pp. 115–196, Taf. I.–V.

Chalk of the Island of Rugen;[1] in the present memoir the Bryozoa of the same formation and locality are described in a similar careful and complete manner, and the new forms, as well as those imperfectly known before, are faithfully represented in the accompanying ten plates, drawn from nature by the author's hand. This group of organisms was included with others from Rugen in a memoir by von Hagenau[2] nearly fifty years since, but this author freely acknowledged the imperfect character of his work, which, however, he did not live to amend and complete. Dr. Marsson enumerates in the present memoir no fewer than 229 species, of which 84 belong to the Cyclostomata and 145 to the Cheilostomata. The following new genera are constituted, *Cryptoglena, Epidictyon, Cavarinella, Rhipidopora, Clinopora, Crisidmonea, Stigmatocatros, Phormopora, Phormonotos, Phyllofrancia, Pithocella, Solenophragma, Bactrellaria, Coscinopleura, Columnotheca, Tæniopora, Bathystoma, Systenostoma, Platyglena, Nephropora, Lekythoglena, Homalostega, Balantiostoma, Cryptostoma, Dioptropora, Kelestoma, Lagodiopsis, Prosoporella, Pachydera,* and *Stichocados.* Of the species enumerated 117 are peculiar to Rugen, and 96 of these are new forms, but it is probable that many of them will be subsequently discovered in other localities. It is certain, however, that a great many are limited to the Rugen Chalk, and no traces of them appear in the same formation of England or France. Four species extend down to the Neocomian, one to the Gault, 21 to the Cenomanian, and nine to the Turonian. With the Chalk of Maestricht there are 45 species in common. Only five species reach upwards to Tertiary strata, and one of these, *Entalophora virgula,* v. Hag., has survived to the present time, Mr. Waters stating that he can discover no differences between the fossil and existing forms.

G. J. H.

III.—Geologie von Bayern. Von Dr. R. Wilhelm von Gümbel. Erster Theil: Grundzüge der Geologie. Lieferungen 1–5. Large 8vo. pp. 1087. (Kassel, 1884–7, Theodor Fischer; London, Williams and Norgate.)

WITH the lately-issued fifth part, the first volume of the 'Geology of Bavaria' is completed; it contains 1078 pages of printed matter and very numerous illustrations in the text; thus forming a massive volume. This first volume is entirely devoted to the "Grundzüge der Geologie," and it has no special bearing on the 'Geology of Bavaria,' which is reserved for the second volume. It forms a very comprehensive and complete Manual or Handbook to Science, and may fairly claim a position equal to that held by our English Text Book of Geology by Dr. Geikie, and by Lapparent's Traité de Géologie in France.

The subject is treated under three heads: (I.) Hylology of the Earth; (II.) Formation of the Earth, or Geotektoriek; and (III.) Geogeny, or the History of the Earth's Development. Under the

[1] id. 12 Jahrg. 1880, pp. 1–50, Taf. i–iii.

[2] Monogr. der Rügens'chen Kreide-Verst. 1839.

first heading is comprised a very full description of the mineralogical and petrographical constituents of the Earth's crust, and their microscopical characters are particularly well illustrated. This is followed by a section on the Morphology of the rocks and of the Crust of the Earth formed by them, and their origin and formation are treated in another section. A general review of the different organisms occurring as fossils is also included in the Hylology, and figures are given of the principal representatives of each group.

Under the second heading of the Formation of the Earth, the Archæolithic, Palæolithic, Mesolithic, Kænolithic, Post-tertiary and Novär or Recent Groups are described, and their mode of occurrence and development in different parts of the Earth are fully referred to. Figures are given of the most typical sections in various countries and of the leading fossils of each group.

In the third division of Geogeny or history of the Earth's development, the relations of the Earth to the universe and to the solar system are considered, as well as its individual character as a planetary body. In the concluding sentence of this division and of the book the author states, that if from a geological standpoint we may draw a conclusion as to the future of the Earth from its past history, we may look forward to an almost unending period, as measured by human standard, of still higher development, and in the furthest distance there is the probabality of a gradual and finally complete refrigeration and the exhaustion of its waters. G. J. H.

IV.—Les Eaux Souterraines à l'Epoque actuelle; leur régime, leur température, leur composition au point de vue du rôle qui leur revient dans l'économie de l'écorce terrestre. Par A. Daubrée, Membre de l'Institut, etc., etc. Two vols. pp. 757, with numerous illustrations. (Vve. Ch. Dunod, Éditeur, Paris, 1887.)

THIS important work bears about the same relation to "Les Eaux Souterraines aux Époques Anciennes," reviewed in our last Number, as the "Principles of Geology" does to the "Elements," inasmuch as it treats of causes now in operation. The author, from the position occupied by him, has had great opportunities for acquiring information on this most extensive subject from all quarters of the world, and the work consequently is the result, in part, of his own large experiences, and partly a selection from the information afforded by other writers.

The first book, which is also the largest and most important, contains seven chapters devoted to the consideration of the phenomena in connection with the system (régime) of underground waters. He commences with an allusion to quarry-water, giving an extract from the results of M. Delesse of the weight of quarry-water per hundred of the wet mass, ranging from 20·66 in white chalk to 0·08 in vein-quartz. In a previous review of Mons. Daubrée's great work (Études synthétiques de Géologie expérimentale) mention was made of the important part which this same quarry-water plays in the economy of the Earth's crust, and of the interesting experiments

of the author by way of showing how it can make its way against a powerful pressure of steam. This has an important effect in the general mechanism of infiltration (vol. ii. p. 214), and helps to overcome the obvious difficulty with respect to water circulating in open fissures, which would appear liable to be forced back by pressure from within.

After giving a description of the permeable and impermeable rocks, the author discusses the phenomena in connection with the more superficial sheets of water, such as have no impermeable bed above them. Having rather a partiality for Greek compounds, he designates this "Phreatic Water." The water-line, or upper level of this sheet, ranges from a few feet to 100 mètres or more. This "Phreatic," or well-water, is largely distributed throughout Drift beds (Terrains de transport), and many plans and sections are given showing its "régime" in different towns of Europe. He quotes from Prestwich's address to the Geological Society (1872) with reference to the water-bearing gravels of London which repose on an impermeable clay, and relates how that, before the great water companies furnished an independent supply, the metropolitan population was largely confined to the water-bearing gravels. Curiously enough, in order to illustrate this, a section is given of the aquiferous gravels at Oxford resting on the Oxford Clay. Not the least interesting account of the superficial sheet of underground water is that relating to the Fontanili of Lombardy, illustrated as usual by small plans and sections. The inhabitants of the favoured district are in the habit of knocking out the bottom of a tall cask, and placing it in an aquiferous bed, some two or three mètres below the surface, when the pressure raises the water in the shaft or funnel thus formed, and a notch being cut in the upper rim, the surplus water is thus conducted into channels of irrigation, much on the principle of water meadows in the South of England. The water-bearing strata of Lombardy above referred to occur in the gravels and sands of old and modern alluvions, and the water which they contain percolates towards the great rivers to such an extent as to restore to these the water of which the numerous irrigation canals had deprived them.

The "Phreatic Water" is by no means confined to the Drift, as of course beds of Tertiary, Cretaceous, Jurassic age, etc., contribute their quota when these occupy the surface of a country. Under this heading some interesting details are given of the well-water of Paris, which, it appears, is contained partly in the alluvium and partly in permeable Tertiary beds upheld by the Plastic Clay. Since M. Daubrée has so extremely enriched his work with plans, sections, photographs, etc., a section across the valley of the Seine at Paris in illustration of these interesting details would have helped the reader, who is not a little puzzled to find a plan apparently of the alluvial deposits near Paris immediately under the heading "terrains tertiaires des départements de la Seine, etc."

The results of contact between permeable and impermeable rocks are next discussed. The contact may be the result of simple stratification, as when sands or gravels overlie clay. The section at

Oxford, after Prestwich, which had already appeared on page 42, vol. i. *à propos* of the "Phreatic Water," is again introduced at p. 73, but it is difficult to say that it illustrates anything very special. Numerous other sections are given in illustration of the subject. Contact by accidents posterior to the stratification is next considered; such as the accumulation of water in decomposed granite or growan, the granite itself being of an impermeable nature. Then, again, there are the phenomena presented by slips or talus, such as that shown at the source of the Creux-du-vent, where the spring has been displaced by a great slip on the flanks of a precipice of Jurassic rock (p. 93, vol. i.). There are also great accumulations of water in porous volcanic ejectamenta, which are thrown out in contact with more compact rocks. Some curious instances in Central France are given with plans and pictorial illustrations. Faults, of course, are well known to produce springs by bringing sandstones, limestones, etc., against clays. Such an one occurs in the neighbourhood of Loudun, where Mesozoic beds are represented (section, vol. i. p. 111) as being traversed by a fault of considerable throw, which is vertical or even slightly reversed.

The most important chapter in the book is entitled "Rôle des lithoclases de divers ordres." M. Daubrée has a partiality for subdivision; and, as we have already seen, for Greek compounds. He had previously given us some interesting phenomena in connection with faults (failles), but much the same things now figure under the far grander title of "paraclases." Joints he calls "diaclases"; whilst another class of fractures, many exceedingly minute, he calls "leptoclases." To a subdivision of this latter, called "synclases," he refers those fractures due to contraction. The whole are summarized under the general term "lithoclases." The upshot of all this is, that rocks are fractured in various ways, by various agencies and in different degrees, and of course such fissures facilitate the accumulation and circulation of underground waters. Under the general heading of "lithoclases" he appears to include the artificial piercing of rocks and artesian borings.

Mons. Daubrée has now fairly settled down to his work (Rôle des lithoclases), and once more takes us through the formations in succession, no longer dealing with the mere top-water (Phreatic) of ordinary wells, however deep, but showing us the mechanism of underground waters in its more complex phases. Considered as a whole the Paris basin is eminently suitable for the making of artesian wells. The beds there are disposed in the form of bowls of decreasing size placed one within the other, the position of Paris itself being almost central with regard to them. These formations, alternately permeable and impermeable, are very slightly disturbed; many levels furnish hundreds of artesian wells, whose depth varies habitually from 10 to 30 mètres. For further particulars he refers to the "Guide du sondeur" by Degousée and Laurent. These remarks refer to the Tertiaries. and under the same heading he gives us an interesting account of artesian borings in the Sahara of Touggourt, to the south of Biskra. The first artesian wells of this

region (the Oued-Rhir) are very ancient, and there are reasons for supposing that the employment of this method of obtaining water was older than the Arab conquest of the country. He then enumerates and partly illustrates by plan and section, as many as five distinct artesian basins, in a traverse from south to north through the Province of Constantine, corrresponding to the undulations of the Quaternary (?) beds of the Sahara.

Under the heading "terrains crétacés" important plans and sections are given of localities in France. Not the least interesting are the phenomena in the Department of the Aube, where the waters percolating the porous Upper Chalk are thrown out by the lower marls. It is thus that the base of the chalk cliff is marked by numerous springs, some of them powerful enough to turn mills; amongst these is the source of the Vanne beneath the village of Fontvannes, which affords a supply of water to Paris itself. The spring of La Folletière in the Calvados boiling up from the glauconitic chalk is pictorially represented. But the most important of all under the heading "Cretaceous" is the account given of the artesian borings at Paris itself, which, as previously observed, is in the centre of one of the most perfect basins perhaps to be found anywhere. The boring at Grenelle, which occupied seven years, after traversing some 50 mètres of Tertiary beds and the whole of the White and Grey Chalk, attained a depth of 547 mètres, when water was found abundantly in the Greensand. A section of this pioneer deep-boring, drawn to scale, together with certain well-known buildings of Paris for comparison, will be found on page 210, vol. i. Many interesting details of subsequent borings are also given. Dealing with the English Cretaceous, Mons. Daubrée reproduces some of the sections of Mr. Lucas with respect to the North Downs, and of Mr. Robert Mortimer with respect to the Chalk Wolds of Yorkshire. From the latter writer many interesting facts connected with this subject are abstracted; but a portion of these is unfortunately placed under the heading "Oxfordshire and Whitshire," betraying an indifference to British geography of which we have a further example (p. 351, vol. i.), where the author seems to fancy that the Swallow-holes of Ingleborough and Castleton are in the neighbourhood of Bristol! Still dealing with the Cretaceous, he adduces many important instances in relation to springs, etc., more or less illustrated by plans and sections, from the north of France, Belgium, Westphalia, etc., touches very briefly upon Ireland, and concludes by reproducing some very elaborate sections by M. Dru relative to the Caucasus.

The beds of Jurassic age, as M. Daubrée remarks, with their fissured limestones and stiff marls or clays, are eminently calculated to produce springs. Many interesting cases are quoted, and amongst others he reproduces a section through Rutland by Prof. Judd, which is intended to show two separate water-lines, one at the junction of the Inferior Oolite and Upper Lias, the other at the junction of the Marlstone-rock with the clays of the Middle Lias. We may here take the opportunity of observing that few places in England present

such a number of boiling springs, or river-heads, as does the Vale of Pickering in East Yorkshire, where the porous and fissured Tabular Hills, composed mainly of Corallian rocks, sloping and dipping to the south, are underlain by Oxford Clay, and faulted against the Kimmeridge Clay, capped by Drift, forming the Vale itself. This region illustrates most admirably not only the "Rôle des lithoclases," but also the "Rôle du contact," etc.

After dealing with the Trias and Permian, the Palæozoic and Crystalline rocks, M. Daubrée concludes this important chapter by considering the phenomena in connection with metalliferous veins. But that these latter are discussed more fully in the companion work (Les eaux souterraines aux époques anciennes), the subject might seem to be treated somewhat briefly, since, from a geological point of view, there can be no more interesting theme than the connection between existing mineral springs and the associated deposits in the fissures through which such waters have passed. Instances are quoted from Plombières, Carlsbad, etc.; in the latter case with ample illustration, the main point being to show that the hot springs of the region of the Sprudels occur at the intersection of two systems of fracture.

The part played by caves in the system of underground waters is treated fully by the author; and since this division of the subject lends itself to pictorial illustration, there are several photographs of well-known sources. The fountain of Vaucluse is one so celebrated that Mons. Daubrée dwells at considerable length on its details as related by the MM. Bouviet. Truly a river of limpid water, full of trout and eels, issuing out of the hard and arid Urgonian limestone, it is just one of those spots which have given rise to all sorts of ingenious and even romantic speculations. It seems to be the sad mission of scientific inquiry to knock all these sort of notions on the head. Given a region of some hundreds of square kilomètres of arid limestone without springs or wells, and at the same time seamed by dry ravines—if rain falls on such a desert in any quantity, a portion of this water must have an outlet somewhere. The conditions which determine the discharge are perhaps more complex than in the case of mere surface drainage.

The remainder of Book I. is occupied with the consideration of the phenomena of water forced upwards by the pressure of its own or of other gases. The various sprudels and so-called mud volcanoes come under the latter denomination. Very interesting details are given of a boring at Montrond (Loire). The phenomena of geysers are then dealt with, not forgetting those of the Yellowstone Park, and of New Zealand. Before dealing with actual volcanoes, M. Daubrée introduces the subject of "soffionis," *i.e.* jets of vapour endowed with a high temperature, which are projected from certain fractures of the ground. The best examples of this class occur in the boracic arid district of Tuscany, of which a tolerably full account is given, accompanied by many illustrations. According to the section (vol. i. p. 405), the country consists of Pliocene clays, Eocene limestone and shales, Cretaceous beds and Lias, all considerably plicated,

and having a bed of serpentine interposed between the two Tertiary deposits. The pipes supplying the soffionis are represented as cutting across the several formations, but no suggestion as to their primary source is offered. With respect to volcanoes, M. Daubrée observes that in spite of the idea which they suggest generally of melted rocks originating in the dry way (voie ignée)), before all things they represent supplies of water, since everywhere the vapour of water is one of the principal products of their activity. An effective cut of the explosion of Krakatau helps to illustrate this.

Book II. supplies us with some valuable facts relative to the temperature both of cold and hot springs.

Book III. deals with the composition of underground waters, First of all the author enumerates the substances dissolved or chemically deposited by them. Speaking generally, one may say that nearly all the elements or their primary compounds exist dissolved in water *somewhere*, either with or without the aid of other solvents; but sulphur, silica, and carbonate of lime are amongst the most abundant deposits. By way of illustration Mons. Daubrée gives a photograph of the mud springs with sulphur at Crater Hill after Hayden, and many other pictorial representations of silica and limestone deposits, taken from various quarters of the globe. Most of these are now in full operation. Compounds of aluminium are rare; nevertheless the hydrous silicates of that mineral, such as allophane, are still being deposited. With respect to the classification of mineral waters Mons. Daubrée will not admit of any preconceived ideas: the predominating substances must decide the grouping. The families are classified according to the principal electro-negative element, as chlorides, sulphides, sulphates, carbonates and silicates: the genera by the principal electro-positive (basic) element, as sodic, calcic, magnesic, etc. Under such an arrangement the waters of the Old Sulphur Well at Harrogate, which is a "strong saline sulphur" containing about 1000 grains of haloid salts to the gallon, would be classified as a brine, in spite of its free hydrogen sulphide and its five grains per gallon of sodium sulphydrate appealing alike to the taste and smell. At the same time it is not easy to say where Mons. Daubrée would draw the line, since he cites a spring at Barèges as a sulphur water which contains 0·04 grms. of sulphide of sodium to the litre out of 0·11 grms. of fixed substances, *i.e.* rather more than one-third. This is what would be called a "pure sulphur water" in the language of the Harrogate doctors.

The silicated waters (sources silicatées), as Mons. Daubrée justly observes, are of the highest interest to the geologist. The silica would usually seem to be in combination with soda, but weighable quantities of the silicates of lime, magnesia and alumina have been found in a water of the Hautes-Pyrénées.

After glancing at the reactions of underground waters on the material bathed by them, the author proceeds to consider the origin of the substances dissolved in the water or chemically deposited by them. Amongst the most obvious are the filth of cities draining into rivers and contaminating the waters of shallow wells; then

there are rocks soluble in water, such as rock-salt and gypsum, and the carbonates, which require the aid of free carbonic acid in the waters, rocks whose decomposition produces soluble matter such as pyrites, etc., etc. Also water charged with saline matter probably possesses greater solvent powers over certain substances. The author then considers the principal elements and source of these compounds in succession in a tolerably long chapter.

In a fourth book Mons. Daubrée makes some general observations relative to the subject, and especially discusses the origin of the temperature of underground waters. Again he illustrates the subject with numerous sections, showing from instances culled in all directions how the result may be influenced by plications of the strata at high angles, whereby the waters are drawn down through synclinal folds to depths where considerable elevation of temperature obtains. Even extinct volcanoes, and rocks of volcanic origin, such as basalts and trachytes, retain sufficient heat to influence the waters which percolate them. Asia Minor, for instance, is a country exceptionally rich in thermal springs. The subject of geysers and volcanoes is again resumed. With regard to the latter, Mons. Daubrée quotes Mr. W. L. Green, who has studied the Hawaiian volcanoes, to the effect that in the eruptions of that archipelago the vapour of water has only played a secondary part. This is an important quotation in view of M. Daubrée's previous assertions with respect to the functions of underground waters in these phenomena. It also bears upon a question which has of late much engaged the attention of Prof. Prestwich and other writers. Lastly, Mons. Daubrée discusses the part which water may play in earthquakes.

An index of subjects, a second of localities, and a third of authors, accompanies the work, which, although having no special claim to originality, constitutes a valuable text-book on the question of underground waters, considered under almost every aspect which can well be conceived. For geological purposes it also affords a good introduction to the companion work already noticed, which is likewise provided with copious indexes.

W. H. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

November 23, 1887.—Prof. J. W. Judd, F.R.S., President, in the chair.—The following communications were read:—

1. "Note on a New Wealden Iguanodont, and other Dinosaurs." By R. Lydekker, Esq., B.A., F.G.S.

The new species of *Iguanodon* was founded upon a left ilium and ischium, parts of the pubis and tibia, two metatarsals, several dorsal lumbar and caudal vertebræ and other bones, obtained by Mr. C. Dawson, F.G.S., from the Wadhurst clay of the Hastings Sand. The species now described, which was named after the discoverer,

and *Iguanodon Prestwichi*, were shown to form a peculiar and aberrant group of the genus *Iguanodon*. A maxilla from the Wealden of the Isle of Wight was also described and referred to *Ornithopsis*.

The recent examination by the author of the remains of Dinosauria in the British Museum for the purpose of preparing a catalogue, had enabled him to make several notes on the various forms represented in the collection, and these notes were embodied in the present paper. The principal subjects mentioned were the following:—The identification of *Iguanodon Seeleyi* with *I. bernissartensis*; the genera *Sphenospondylus* and *Cumnoria* of Prof. Seeley; a British species of *Trachodon* from the Cambridge Greensand; an ilium, provisionally referred to *Hylæosaurus*, from Cuckfield; the genera *Vectisaurus* and *Regnosaurus*; the relations of the Sauropoda and Theropoda; the type specimen of *Ornithopsis Hulkei*; the similarity of the humerus in *Pelorosaurus* and *Brontosaurus*; the vertebræ and other remains of *Cetiosaurus brevis*; the humerus of *C. humerocristatus* and its relations to *Ischyrosaurus*, Hulke, *Gigantosaurus*, Seeley, and *Ornithopsis Leedsii*, Hulke; the affinities between *Cetiosaurus oxoniensis* and *Morosaurus*; the occurrence of *Titanosaurus* in the Wealden of England and the possible identification of that genus with the *Dinodocus* of Owen; the vertebræ described by Owen as *Bothriospondylus magnus*; the types of the genera *Thecospondylus* and *Bothriospondylus*; and some Megalosaurian teeth.

2. "On the Cae-Gwyn Cave." By T. McKenny Hughes, M.A., F.G.S., Woodwardian Professor of Geology, Cambridge.

The subject fell into two divisions: The Age of the Drift outside the Cave, and The relation of the deposits in the Cave to that Drift. The author contended that the drift outside the cave was a marine deposit *remanié* from older beds of glacial age, but was itself post-glacial and of approximately the same date as the St. Asaph drift; in confirmation of which he gave the following list of shells from that drift outside the cave:—*Ostrea edulis*, *Pecten varius*, *Mytilus edulis*, *Cardium echinatum*, *C. edule*, *Cyprina islandica*, *Astarte borealis*, *A. sulcata*, *A.* var., *Venus gallina*, *Tellina balthica*, *Psammobia ferroensis*, *Mya truncata*, *Fissurella græca*, *Littorina littorea*, *Turritella terebra*, and *Buccinum undatum*; pointing out that there was only the one species of *Astarte* among them which was not common on the adjoining coast, just as there were in the older post-glacial river-gravels of the S.E. of England two locally extinct forms, the *Corbicula fluminalis* and the *Unio littoralis*, and discussing various difficulties, stratigraphical and palæontological, in the way of accepting the view that the cave-deposits were glacial, interglacial, or preglacial. For instance, he remarked that there were no marks of glaciation on the face of the rock in which the cave occurred; that the cave-deposits were like drift because derived from it, but that no continuity existed between the drift and the cave-deposits; that there was a much greater thickness of rain-wash and resorted marine-drift looped down over the upper opening into the cave than over the adjoining surface. The upper part of this

resorted drift is exactly similar to the material which had accumulated against the old fence, the very existence of which had been denied. The swallow-hole action to which he referred the phenomena was proved by the opened fissures and vertical cylindrical holes in the limestone and by the occurrence of a land-shell (*Zonites cellarius*). He held that there had been a breakdown of the roof and wall of the cave under the drift, and that angular masses of limestone, due to this cause, were found all along in front of the upper opening to the cave. No bones were found outside that barrier, there being no bones in the shell-bed and no shells in the bone-bed except the land-shell washed down through a fissure.

Instead, therefore, of the difficult task of proving that there were in the district many well-known processes connected with subterranean denudations, which might explain the superposition of the marine drift upon the bone-earth, each of which had played a part in producing the results observed, he maintained that we had now the clearest evidence as to the exact manner in which it was all brought about, namely, that the marine drift was deposited before the occupation of the cave by the animals whose remains have been found in it; that at the time of the occupation of the cave the upper opening now seen did not exist, but the animals got in by the other entrance; that against the wall of the cave where it approached most nearly to the face of the cliff, the drift lay thick as we now see it; that by swallow-hole action the cave was first partially filled, and then the thinnest portion of its wall gave way gradually, burying the bone-earth below it, and letting down some of the drift above it, so that some of it now looks as if it might have been laid down by the sea upon preexisting cave-deposits.

II.—December 7, 1887.—Prof. J. W. Judd, F.R.S., President, in the chair.—The following communications were read:—

1. "A Letter from H.M. Secretary of State for the Colonies, enclosing an account of recent Discoveries of Gold in the Transvaal."

The deposits in which gold has been found, locally known as "banket," consist of a quartz-conglomerate forming so-called "reefs," which traverse the veldt paralled to, but at a short distance from the rocky ridge of Witwatersrand. These masses always dip to the south, but at angles varying from 30° up to 90°. The "reefs" are believed to have been discovered by Mr. Struben, an English gentleman long resident in the country. The "main reef" has been traced for twenty-five or thirty miles, and varies in breadth from 3 feet 6 inches to 15 feet; parallel and branching "reefs" of smaller dimensions have also been found. The yield of gold is said to be very variable in different portions of the "reef," different samples with from 3 oz. to ½ oz. per ton occurring in close proximity. So far as observation has gone (and the deepest workings have only reached a depth of from 70 to 150 feet), the yield of gold has generally increased as the reefs are followed downwards.

2. "On the Age of the Altered Limestone of Strath, Skye." By Dr. Archibald Geikie, F.R.S., V.P.G.S.

The remarkable alteration of the limestone of Strath into a white saccharoid marble, first described by Maculloch, has hitherto been regarded as an instance of contact-metamorphism in a rock of Liassic age. The various writers who have described the geology of the district have followed Macculloch in classing the whole of the ordinary and altered limestone with the Secondary series of the Inner Hebrides. The author, however, saw reason in 1861 to suspect that some part of the limestone must be of the age of the Durness Limestone of Sutherland, that is, Lower Silurian; and he expressed this suspicion in a joint paper by the late Sir R. I. Murchison and himself, published in the 18th volume of the Quarterly Journal of the Society. He has recently returned to the subject, and now offers lithological, stratigraphical, and palæontological evidence that the altered limestone is not Lias, but Lower Silurian.

In lithological characters the limestone, where not immediately affected by the intrusion of the eruptive rocks, closely resembles the well-known limestones of the west of Sutherland and Ross-shire. It is not more altered than Palæozoic limestones usually are. It contains abundant black chert-concretions and nodules, which project from the weathered surfaces of the rock exactly as they do at Durness. These cherts do not occur in any of the undoubted Lias limestones of the shore-sections. The limestone lies in beds, which, however, are not nearly so distinct as those of the Lias, and have none of the interstratifications of dark sandy shale so conspicuous in the true Liassic series.

The stratigraphy of the altered limestone likewise marks it off from the Lias. There appears to be a lower group of dark limestones full of black cherts, and a higher group of white limestones with little or no chert, which may be compared with the two lower groups of the Durness Limestone. A further point of connexion between the rocks of the two localities is the occurrence of white quartzite in association with the limestone at several places in Strath, and of representatives of the well-known "fucoid beds" at Ord, in Sleat. These latter strata form a persistent band between the base of the limestone and the top of the quartzite, which may be traced all the way from the extreme north of Sutherland southward into Skye.

Palæontological evidence confirms and completes the proof that the limestone is of Lower Silurian age. The author has obtained from the limestone of Ben Suardal, near Broadford, a number of fossils which are specifically identical with those in the Durness Limestone, and so closely resemble them in lithological aspect that the whole might be believed to have come from the same crag. Among the fossils are species of *Cyclonema*, *Murchisonia*, *Maclurea*, *Orthoceras*, and *Piloceras*.

The relations of the limestones containing these fossils to the other rocks were traced by the author. He showed that the Lias rests upon the Silurian limestone with a strong unconformability, and contains at its base a coarse breccia or conglomerate, chiefly composed of pieces of Silurian limestone, with fragments of chert and quartzite. The metamorphism for which Strath has been so long noted is con-

fined to the Silurian limestone, and has been produced by the intrusion of large bosses of granophyre (Macculloch's "syenite") belonging to the younger, or Tertiary series of igneous rocks.

3. "On the Discovery of Trilobites in the Upper Green (Cambrian) Slates of the Penrhyn Quarry, Bethesda, near Bangor, North Wales." By Dr. Henry Woodward, F.R.S., V.P.G.S.

The absence in Wales of organisms in the Longmynd and Harlech group renders any discovery of fossils in beds of this early horizon of the utmost importance.

A portion of a Trilobite (*Palæopyge Ramsayi*) and Annelide burrows had already been found; but Dr. Hicks, at St. Davids, has added a sponge, 2 Ostracods, 6 Trilobites, 2 *Lingulellæ*, and 2 *Thecæ* (*Agnostus, Plutonia, Paradoxides, Conocoryphe Lyelli, C. bufo*, and *Microdiscus sculptus*).

Dr. Hicks has pointed out the singular absence of organic remains in the Longmynds both in Shropshire, N. Wales, and Ireland, and has urged the need of further explorations. As if in answer to this, the author has received from Prof. Dobbie an impression and counterpart of a Trilobite from Bethesda, near Bangor, about $3\frac{1}{2}$ in. long and $1\frac{3}{4}$ in. broad, also the head of a second specimen of the same species. These specimens were obtained from the Upper Green bed of the quarry, which immediately underlies the grits forming the brow of Bronllwyd and overlies the Purple Slate. The glabella is marked by three oblique furrows on each side, the cheek-sutures are very obscure, and the eyes, which are minute (probably rudimentary), occupy the centre of the free cheek, the suture obliquely dividing the free cheek from the fixed. The outline of the head is rounded. There are fourteen free thoracic segments. The pygidium consists of about three coalesced somites.

Comparing the Bangor fossil with *Paradoxides*, we find that *Paradoxides* has about twenty free segments.

Asaphus, Ogygia, and *Niobe* have only eight thoracic rings, and the caudal shield is very large.

Angelina agrees with the Bethesda specimen in the number of its free segments; but the glabella is smooth, the pleuræ are broader, and the cheek-spines very long.

Olenus has fourteen rings; the glabella is furrowed, but the head-shield is shorter and broader, and the ends of the pleuræ and margin of the caudal shield are usually produced into spines. *Olenus* is also smaller.

Conocoryphe has fourteen free segments; the axis is parallel-sided, and does not diminish backward from the head to the pygidium; each ring of the axis is notched on its posterior border, and the ends of the pleuræ are rounded; the glabella is furrowed obliquely; the eyes are often wanting or are minute.

From these considerations the author concludes the Bangor fossil to be referable to *Conocoryphe*, and to a new species, *C. viola*.

The Trilobite was found by Robert E. Jones and Robert Lloyd, two quarrymen, at Bethesda. Afterwards Prof. Dobbie found a detached head of the same species near the spot where the original

specimen was obtained. The author desires to return thanks to Prof. J. Dobbie, of the University College of North Wales, Bangor, for the opportunity of describing these specimens.

4. "On *Thecospondylus Daviesi*, Seeley, with some Remarks on the Classification of the Dinosauria." By Prof. H. G. Seeley, F.R.S., F.G.S.

The author described the anterior third of a vertebra from the Wealden, which was recognized by Mr. Davies as the cervical vertebra of an animal allied to the genus *Cœlurus*, Marsh. The only European genus hitherto described in which the vertebræ are similarly elongated, compressed, and enveloped in a dense external film of bone is that indicated by the sacrum, named *Thecospondylus Horneri*, whose vertebræ are about 11 centimetres long, whilst the cervical vertebræ now under discussion were 9 centimetres long when complete. The specimen has lost the prezygapophyses and cervical ribs. If these were restored, they would probably approximate in shape to those of *Cœlurus fragilis*.

The author gave an outline-restoration. The points of resemblance were chiefly the elongated form, lateral compression of centrum and neural arch, inclined articular face of centrum, mode of attachment of the ribs, the convex external surface of the neural arch, almost total suppression of the neural spine, and the thin texture of the bone. But this affinity does not amount to generic identity, and he indicates the points of difference. In estimating the resemblance to *Thecospondylus* he regards the thinness of the investing layer of bone, the smoothness of its internal surface, and the elongation and lateral compression of the vertebræ, and a certain general approximation in form; the most remarkable difference is the absence from the cast of *Thecospondylus Horneri* of indications of films of bone, or evidence of internal plates, such as are seen in the present specimen. He observed that Prof. Marsh regards *Cœlurus fragilis* as a generalized Sauropsid, with more resemblance to Dinosaurs than to Pterodactyles.

Professor Marsh has formed an Order, Sauropoda, which includes *Cetiosaurus* and *Ornithopsis*. The author remarks that he had already suggested Cetiosauria as separable from the rest of the Dinosaurs. When an additional Order is instituted for animals with cavernous or pneumatic vertebræ, the Theropoda of Marsh, under which *Cœlurus* is grouped, it becomes necessary, in order to determine the systematic position of *Thecospondylus*, to review its relations. The author would unite Sauropoda with Theropoda into one Order, the Saurischia, whose pneumatic skeleton is an approximation towards Ornithosaurs and Birds.

CORRESPONDENCE.

CLASSIFICATION OF THE DINOSAURIA.

Sir,—Will you allow me to state that I did not forward to the Geological Magazine the abstracts of my British Association papers printed in the December Number, pp. 561–563, and that no proof of those abstracts was submitted to me; so that I am not responsible

for the publication. In the paper on the classification of the Dinosauria, I do not adopt the names given on p. 562; but use the name *Ornithischia* for the order of which Omosaurus is an example, there named Omosauria; while the name *Saurischia* is used for the order comprising allies of Cetiosaurus, there named Cetiosauria. I shall be glad if this erratum is corrected on p. 562, so that the names which appear there may not be quoted, and may be considered not to have been published.

The Vine, Sevenoaks, *Dec.* 3, 1887. H. G. Seeley.

DIMETIAN OF ST. DAVIDS.

Sir,—Mr. Mellard Reade in his paper "On the Dimetian of St. Davids" does not state whether the rock which he found included in the "Dimetian," and which he calls a "green shale," has been proved to be such by microscopic examination. Will he kindly supply the omission; because, without such an assurance, his proof of the intrusive character of the "Dimetian" has no more validity than an arch without a keystone. T. G. Bonney.

PROF. BONNEY ON BANDED GNEISSES AND THE METAMORPHIC ROCKS OF SOUTH DEVON.

Sir,—Would you kindly allow me space for reply to Professor Bonney's letter in your issue for December, on the above subjects, more especially the latter, which directly affects myself. This portion of his letter forms a marked contrast to the other, and at the outset I beg to protest against its style and tone, which I shall not condescend to imitate in this reply.

It is possible or even probable that I may be wrong in my interpretation of these South Devon rocks, and if so, on further and better proof I shall be as happy in the opposite conclusion, as I earnestly trust that I follow science or truth for its own sake.

With regard to the use of the microscope in geology, let me respectfully remind Prof. Bonney that it is not everything. It so happens that I too have a stake in the "banded gneisses" of the Lizard district, and my field-work there showed me that the whole of his "granulitic" group of schists were rocks of true igneous origin, a fact forced upon me without the aid of the microscope; and further, that the other schists in which the Professor describes current-bedding and ripple-drift, etc., etc., I strongly suspected to have had also an igneous origin, and these appearances due to very different causes, facts which have since been corroborated by a high authority. So much for the use and non-use of the microscope, an instrument in research which I do not undervalue, and which I mean to become better acquainted with.

It is, however, against the tone of the Professor's letter that I complain, and I would invite him (and the rest of your interested readers) to compare the portion of it relating to myself with the last paragraph of his own article in "Nature" for November 10th.

59, Fleet Street, Torquay, *Dec.* 15, 1887. Alex. Somervail.

THE MAMMOTH AND THE FLOOD.

We have received a somewhat lengthy communication from Mr. H. H. Howorth, M.P., in which he reminds us that so recently as 1880 Sir Andrew Ramsay expressed the opinion that "from the Laurentian epoch down to the present day, all the physical events in the history of the earth have varied neither in kind nor in intensity from those of which we now have experience." (Address to Geol. Section, Brit. Assoc., Swansea.) We are glad to be in sympathy with Mr. Howorth in his opposition to this doctrine, but we do not believe it is upheld by many geologists at the present day, nor is it taught in modern text-books. (See Geology, by A. H. Green, Ed. 3, 1882, pp. 694—696; Text-Book of Geology, by A. Geikie, Ed. 2, 1885, pp. 3, 178; Outlines of Geology, by James Geikie, 1886, p. 3.)

Mr. Howorth contends that over the greater portion of the Earth's surface there is no such denudation going on (or even possible) as that which has taken place in past times. We have not disputed the notion that excessive denudation may have taken place in former times, for instance, during the Glacial period. Mr. Howorth, however, objects to the employment of the term Denudation to include the action of springs and rivers in carrying away the soluble constituents of rocks! We are aware that *literally* the term is inapplicable, but in nearly every geological work it is used to signify the removal of material from any portion of the land. Mr. Jukes-Browne has indeed suggested that the word Detrition be used in this sense in place of Denudation, but we are averse to the introduction of new names, when the old ones are sufficiently intelligible. In reference to this subject we may refer Mr. Howorth to a work by Mr. Mellard Reade on "Chemical Denudation in relation to Geological Time." EDIT. GEOL. MAG.[1]

THE DIMETIAN OF ST DAVIDS.

SIR,—Mr. Mellard Reade's paper in the GEOLOGICAL MAGAZINE for December on the Dimetian of St. Davids contains such striking evidence of a want of acquaintance with the subject, and such hasty conclusions founded on erroneous observations, that I should not consider it necessary to reply to it, were it not that a definite piece of so-called evidence is given which may lead to some misapprehension if not corrected.

The piece of evidence which he gives to prove "that the rock is not in any sense Archæan, but is post-Cambrian, and intrusive," occurs in the following passage relating to the sections at Porthclais: "At a distance of about 30 feet north of this contact and embedded in the granite is a vein of green shale about 18 inches across and another about 10 feet nearer to the contact about six inches across.

[1] As Mr. Howorth reminds us in his letter that the more important issues raised by his Reviewer (see GEOL. MAG. October 1887, p. 473) can only be properly discussed when his second volume appears, we are content to await the issue of that work—the limited space at our disposal not admitting of the publication of lengthy letters in reply to Reviews.—EDIT. GEOL. MAG.

Both these veins of shale, but especially the thinner one, have a rudely columnar structure at right angles to their direction. Excepting that this shale is a little more indurated and more like slate in its constitution, it is similar to the Cambrian green shales that overlie the basal conglomerate. These veins are in my view undoubtedly part of the Cambrian shale entangled in the granite, so that the granite must be post-Cambrian."

Now, Sir, these veins are perfectly well known to all who have examined the sections at Porthclais, but it has been reserved for Mr. Reade to venture to call them Green Cambrian Shales. Those who have examined these veins with any care have had no difficulty in recognizing in them the ordinary behaviour of igneous rocks, and in proving after a microscopical examination that they are diabase dykes! Such dykes, as is well known, are common in the Dimetian, and they have been frequently referred to in my papers. Mr. Reade would therefore have acted more wisely, if, before publishing his views, he had taken the trouble to read more of what had been written on the subject, and also had consulted a petrologist as to the nature of the rocks he was dealing with.

HENDON, *Dec.* 3, 1887. HENRY HICKS.

ON *ETOBLATTINA*, A LARVAL COCKROACH FROM THE COAL-MEASURES OF KILMAURS, AYRSHIRE; DISCOVERED BY MR. LINTON, OF KILMARNOCK.

MY attention has been called by Mr. Robert Kidston, F.G.S., to a serious omission made by me in my notice of *Etoblattina Peachii* in the GEOLOGICAL MAGAZINE for October, 1887, p. 432.

It is true that the specimen was forwarded to me by my friend, Mr. B. N. Peach, of the Geological Survey of Scotland, but I am now informed that it was found by a private geologist, Mr. Linton, of Kilmarnock,[1] and he it was (and not the friend who sent it to me) whom I should have specially mentioned as being the discoverer. I regret exceedingly my carelessness in not making further inquiries of Mr. Peach as to its ownership before setting out to describe this interesting Carboniferous treasure, and I take this opportunity to thank Mr. Linton most cordially for placing it so generously at Mr. Kidston's disposal for examination. We are all so deeply indebted to the persevering labours of such private geologists, as Mr. Linton, that I, for one, would be the last to omit to award them their full meed of honour.

129, BEAUFORT STREET, S.W. HENRY WOODWARD.

[1] This gentleman entrusted it to Mr. Kidston to be described. Mr. Kidston transferred it to Mr. Peach, who subsequently transmitted it to the writer.—H.W.

WESTERN AUSTRALIA.—MR. HARRY PAGE WOODWARD, F.G.S., F.R.G.S. (eldest son of Dr. Woodward, F.R.S., V.P.G.S.), who served for more than three years under Mr. H. Y. L. Brown, F.G.S., as Assistant Government Geologist in South Australia, has been appointed by Her Majesty's Secretary of State for the Colonies to the post of Government Geologist for Western Australia. Only a very small portion of this, the largest of the Australian Colonies, has at present been examined by a geologist. Mr. Woodward left for Perth on the 2nd of December last.—*The Times*, Dec. 8, 1887.